Science Policy Study—Hearings Volume 3
THE RELATIONSHIP OF INDUSTRIAL BASIC AND APPLIED RESEARCH TO GOVERNMENT SCIENCE POLICY

HEARINGS

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

APRIL 23, 24, 1985

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CONTENTS

WITNESSES

April 23, 1985:

	Page
Jesse M. Smith, Jr., executive director, College Placement Council, Inc., Bethlehem, PA	3
Prepared statement	18
Discussion	35

Panel: Industrial Research Management

William A. Stickel, director, patents and licensing, Corporate Research and Technology Assessment, United States Steel Corp., Pittsburgh, PA	44
Prepared statement	48
Dr. Samuel W. Tinsley, director of technology planning, Union Carbide Corp., Danbury, CT	61
Prepared statement	63
Dr. Keith W. McHenry, Jr., vice president, research and development, Amoco Corp., Naperville, IL	66
Prepared statement	71
Panel discussion	91

Panel: Academic Overview

April 24, 1985:

Dr. Zvi Griliches, Nathaniel Ropes Professor of Political Economy, department of economics, Harvard University, Cambridge, MA	101
Prepared statement	107
Dr. David C. Mowery, assistant professor of economics and social sciences, Carnegie-Mellon University, Pittsburgh, PA; and research associate, Stanford University Center for Economic Policy Research, Stanford, CA	115
Prepared statement	119
Panel discussion	126
Dr. W. Clarke Wescoe, chairman of the board, Sterling Drug Co., New York, NY, accompanied by Gerald J. Mossinghof, Pharmaceutical Manufacturers Association, Washington, DC	130
Prepared statement	135
Discussion	140
Dr. Alexander Mac Lachlan, director, Central Research and Development Department, E.I. du Pont de Nemours & Co., Inc., Wilmington, DE	143
Prepared statement	147
Discussion	155
Dr. Eugene E. Yore, vice president of precision weapons operations, Honeywell Defense Systems Division, Honeywell, Inc., Minneapolis, MN, and former project manager, Task Force on Research and Development, the President's Private Sector Survey on Cost Control (Grace Commission)	159
Prepared statement	164
Discussion	183
Appendix 1: Testimony submitted by Dr. Edwin Mansfield, director, Center for Economics and Technology, and professor of economics, University of Pennsylvania, Philadelphia, PA	187

Page
Appendix 2: Questions and answers for the record submitted by Dr. Alexander Mac Lachlan 198
Appendix 3: "Task Force Report on Research and Development," Task Force on Research and Development, the President's Private Sector Survey on Cost Control (Grace Commission), submitted to the subcommittee for consideration at its meeting on December 8, 1983 228
Executive summary 240
The Report Recommendations—A Perspective 245
I. Introduction 248
II. Issue and recommendation summaries 261
  R&D 1: Strategic planning 261
  R&D 2: R&D management and the budget process 285
  R&D 3: Privatization 306
  R&D 4: Improved management of resources in Federal research laboratories 314
  R&D 5: Administration of research grants to universities 328
  R&D 6: Research program reporting 350
  R&D 7: NASA cost reporting 360
  R&D 8: Compendium of selected R&D issues 365
III. Summary list of recommendations and savings 374
IV. Cost control opportunities for further study 377
V. R&D task force membership 394
Appendix 4: Roland W. Schmitt, "Successful Corporate R&D," *Harvard Business Review*, May–June, 1985, volume 85, No. 3, pp. 124–128 397

THE RELATIONSHIP OF INDUSTRIAL BASIC AND APPLIED RESEARCH TO GOVERNMENT SCIENCE POLICY

TUESDAY, APRIL 23, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 2:05 p.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. The meeting will come to order.

The purpose of this hearing of the Task Force on Science Policy is to review the relationship between industrial basic and applied research and Government science policy.

We recognize that basic and applied research provide the foundation of new technologies and new industries that will sustain U.S. industrial leadership, create new jobs, and improve our standard of living.

In his report 40 years ago to the President entitled "Science—The Endless Frontier," Vannevar Bush stated, "The simplest and most effective way in which the Government can strengthen industrial research is to support basic research and develop scientific talent."

It is important now that we examine research programs in the private sector and measure the effectiveness of past Government science policy in meeting this challenge.

However, just as important as the task force's evaluation of the past is our consideration of future science policy. Several recent estimates indicate that industry performs about 50 percent of the Nation's basic and applied research.

Although recent estimates indicate shifts in industrial support for basic research, it is our understanding that applied research remains much more heavily funded in the private sector.

There may be an increasing role for Government basic research if industry concentrates on application. Conversely, there is the danger, which Bush warned of in his report, that too strong a Government presence in some types of scientific research can serve as a disincentive to private sector research funding on its own account.

We want to examine industrial research management to discover strategies that can be used to improve Federal science policy for the future. This hearing, therefore, will focus on how the decisions are made in industry to establish research support levels, select research programs, and determine long-range basic and applied research goals.

Finally, a study of the relationship of industrial research to Government science policy would be incomplete without consideration of the science and engineering manpower behind research programs. Government-funded research programs at universities help provide the groundwork for industrial research through the training and education of scientists and engineers.

This hearing will look at the effectiveness of Government education programs in meeting industry manpower requirements and compare the private sector responsibility in contributing to the education of scientists and engineers.

I want to thank all of our witnesses today for their willingness to appear before the task force and express their views on these subjects. Their effort and cooperation in preparing testimony for this meeting is truly appreciated by each of the task force members.

Before we call our first witness, at this point in the record we will insert the opening statement of Mr. Lujan, without objection.

[The prepared opening remarks of Mr. Lujan follow:]

OPENING REMARKS
HONORABLE MANUEL LUJAN, JR. (R-NM)
TASK FORCE ON SCIENCE POLICY
APRIL 23, 1985

TODAY AND TOMORROW, THE SCIENCE POLICY TASK FORCE WILL HEAR FROM INDUSTRIAL AND ACADEMIC WITNESSES ON THE RELATIONSHIP OF INDUSTRIAL RESEARCH TO GOVERNMENT SCIENCE POLICY. INITIALLY, WE WILL BE FOCUSING OUR ATTENTION ON THREE ASPECTS OF THIS COMPLEMENTARY RELATIONSHIP: (1) THE AREAS IN WHICH INDUSTRY CONDUCTS RESEARCH AND THEIR FUNDING LEVELS; (2) HOW INDUSTRY MANAGES RESEARCH AND WHETHER THEIR MANAGEMENT TECHNIQUES ARE APPLICABLE TO GOVERNMENT-DIRECTED RESEARCH ACTIVITIES, AND (3) INDUSTRY'S REQUIREMENTS FOR SCIENCE AND ENGINEERING MANPOWER.

TOTAL EXPENDITURES THIS YEAR FOR R&D IN THE U.S. ARE EXPECTED TO BE ABOUT $107 BILLION. THE INDUSTRIAL SHARE OF R&D FUNDING IS ESTIMATED AT A LITTLE OVER HALF OF THIS TOTAL -- ABOUT $55 BILLION -- AND REAL INDUSTRIAL SUPPORT HAS RECENTLY BEEN INCREASING AT A FASTER RATE THAN FEDERAL SUPPORT. OF COURSE, THE FOCUS OF OUR TASK FORCE AND THIS HEARING ARE PRINCIPALLY ON THE BASIC AND APPLIED RESEARCH PORTIONS OF THESE ACTIVITIES, AND NOT ON THE DEVELOPMENT ACTIVITIES WHICH COMPRISE A SIGNIFICANT SHARE OF THE TOTAL FUNDING. BUT EVEN WHEN COMPARING THE FEDERAL VERSUS NON-FEDERAL FUNDING LEVELS IN BASIC AND APPLIED RESEARCH, THE PERCENTAGE OF INDUSTRIAL ACTIVITY IS STILL A LITTLE OVER HALF OF THE TOTAL. IT BEHOOVES US TO DETERMINE HOW WELL THESE GOVERNMENT-FUNDED AND INDUSTRY-FUNDED RESEARCH ACTIVITIES COMPLEMENT EACH OTHER, WHERE THERE MAY BE GAPS OR OVERLAPS, AND HOW THE GOALS OF A NATIONAL SCIENCE POLICY CAN BE DEFINED AND IMPLEMENTED THROUGH THEIR JOINT EFFORTS.

I also look forward to reviewing industrial research management and how these techniques can contribute to improved management of government-directed research. The recent Grace Commission study included a Task Force on Research and Development. As a result of recent authorization activity by the Science Committee, we have asked the appropriate R&D administrators to look at the Grace Commission recommendations which affect their departments, which include proposed management improvements, and report back to us on their implementation status.

The third subject of interest today on science and engineering manpower has been one of continuing interest to the Science Committee and is of such importance that our Task Force has scheduled an additional six days of hearings on the subject in July.

I look forward to hearing from all of the witnesses over the next two days on these subjects and any others which they feel the Task Force should be aware of.

Mr. **Fuqua**. We will begin with Mr. Jesse Smith, the executive director of the College Placement Council, from Bethlehem, PA.

[A biographical sketch of Mr. Smith follows:]

Jesse M. Smith—Executive Director of the College Placement Council, Inc. since October 1977. Prior to his association with CPC he was chairperson of the Department of Management and Finance of Boise State University, managing director of the American Assembly of Collegiate Schools of Business, and assistant dean and instructor at the University of Denver. His background includes seven years of experience in business management with Peat, Marwick, Mitchell and Company and Mountain Bell Company, Denver.

An MBA graduate of the University of Denver, Mr. Smith has served as an academic consultant to eight major state universities and has presented numerous workshops on human relations and planning for government agencies, the U.S. Army, and for private corporations.

STATEMENT OF JESSE M. SMITH, JR., EXECUTIVE DIRECTOR, COLLEGE PLACEMENT COUNCIL, INC., BETHLEHEM, PA

Mr. **Smith**. Congressman Fuqua, we want to thank you and your committee very much for inviting the College Placement Council to appear before the hearings on manpower needs and also on research needs.

Very briefly, the College Placement Council is a nonprofit professional society that interfaces between the world of education and the world of work. Our primary concern is to assist students in making a transition from their higher educational programs into career paths. Consequently, the tasks and concerns before your committee are very much a concern of ours.

I would like to begin by addressing the demand picture as we see it for technical and science majors. Currently, we have approximately 1,200,000 engineers employed in the United States. By 1995, our estimates are that we will have a need for an additional 584,000 technically trained personnel, or roughly a 40-percent increase.

We will also need an additional 600,000 computer science specialists by 1987. This figure represents approximately a 24.7-percent increase above the available supply that we anticipate would be available by 1987.

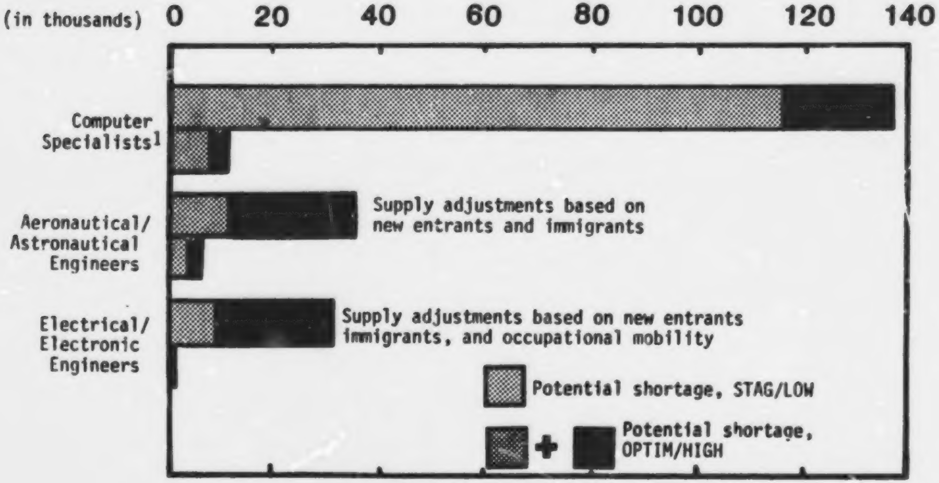
Science employment is expected to increase from 730,000 in 1982 to somewhere between 845,000 and 890,000 by 1987. If you look at specific engineering disciplines and try to anticipate the percent change of jobs in each of those disciplines, they range from a low of 22 percent additional positions for mining and petroleum engineers for the years 1982 to 1995 to a high of 65 percent additional positions for electrical engineers for the same time period.

Mechanical engineers represented an increase of approximately 52 percent positions until 1995. All other engineering disciplines fell in a percent change range of 40 to 49 percent. The openings for computer science specialties are expected to increase on an annual rate approximately double that of engineering specialties.

So we feel that there are a number of key concerns, and I have brought some transparencies which I would like to use to demonstrate, if we can have the screen.

Any time one tries to predict the supply and demand, you have a problem in trying to predict the economy. This chart demonstrates what one sees by looking at the projections with two different assumptions, one being a low assumption for both growth in the economy and the industrial sector, and also a high or optimistic projection.

Potential Science/Engineering Labor Shortages 1987



[1] Includes both computer systems analysts and programmers.

NOTE: STAG/LOW indicates low-economic growth / low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth / high-defense expenditure scenario.

SOURCE: National Science Foundation

The green band represents the projected increase in positions that we anticipate for computer specialists out through 1987. You will notice that it is approximately 118,000 additional positions that we would have to fill. The black indicates a more optimistic projection of those figures.

In looking through the various disciplines and trying to anticipate where the shortages might fall as far as our technical manpower needs, we estimate that the following majors or disciplines will have some significant shortfall in the manpower available. Those are aero/astronautical engineering, artificial intelligence, biomedical, chemical, computer systems, systems analysis, electrical, electronics, mechanical, and robotic disciplines, all in the engineering fields.

Now, let me shift very briefly to the supply side of this equation. Currently, higher education is producing approximately 74,000 baccalaureate graduates in engineering per year. Since it takes approximately 4 to 5 years for an individual to complete a baccalaureate degree, we anticipate that this level will remain fairly constant through the year 1990, since most of those students are already in the system.

We also expect higher education to produce approximately 460,000 computer science specialists by 1987. As you will recall, I indicated that that was approximately 27 percent below the actual demand that we expect.

The main thing, I think, we have to keep in mind is that we have had a peak in enrollments at the traditional freshman level that occurred in 1982–83. Now, this peak primarily is impacting the freshman student, since overall enrollment levels, through the studies that we see, are remaining fairly constant.

But if one takes a look at why they are remaining constant, then you begin to see that the growth rate of women, foreign nationals, and nontraditional students in our degree programs is what is holding our enrollments up. The concern, then, is what is going to happen in the traditional freshman enrollments and, consequently, the traditional graduate in the 21- to 22-year age group.

This chart indicates the amount of growth that has taken place in education from 1972 to 1982, and you will note that the age ranges of 25 to 34 experienced a 69.8 percent growth in those age ranges in higher education. Those above 35 years of age had a 77 percent growth rate in higher education.

Part-time enrollments increased 65.6 percent. All of these are indicating that our student mix at the higher educational level is becoming more and more a nontraditional student mix, relying on other than freshman enrollments, and it is the freshman enrollment that we are concerned about to meet the manpower needs of the future.

If you take and compound this situation with the baby boom bulge that has moved through, then you begin to see an overall impact on higher education that will consequently impact the research capabilities. The baby boom generation is currently impacting the midmanagement ranks of corporate America.

At the present time, we estimate that there are eight qualified individuals for every midmanagement opening. By the end of this decade, we estimate that that ratio will change to in excess of 30 to

1. This is going to cause a tremendous compaction of upward mobility. There is going to be a lot of dissatisfaction on the part of individuals who cannot find upward success tracks and will not be able to explore the kinds of opportunities they would like.

Consequently, we are finding that this particular population is doing a number of things, one of which is returning to higher education to change majors, to enhance their educational programs, and that is why this nontraditional bulge that we see.

They are also moving out of their corporate positions and into a lot of entrepreneurial kinds of operations, and a lot of them are simply leaving their chosen field initially to find some other avenue that might provide them some upward mobility.

Now, a lot of the projections of balance in supply and demand that we hear about are heavily geared to this baby boom generation to be able to make a transition into the demand areas in the technical fields. If they are not there to make the transition, then that projection of some semblance of balance, we think, is going to erode very rapidly.

At the present time, higher education is at a maximum as far as its capacity to train technical people. Now, one thing, I think, we need to take a look at is what has been happening in the rate of change of freshman enrollments.

Just to give you an example, this is a study from the Engineering Manpower Commission. From the fall of 1973 to the fall of 1974, there was a 22.2-percent increase in freshman enrollments in engineering programs. That percent increase declined until, in the fall of 1981 to 1982, there was a zero percent increase; from the fall of 1982 to 1983, enrollments at the freshman level actually dropped 4.9 percent.

Now, if we have peaked in enrollments in 1982–83, and the population of traditional 18 year olds is going to decline for the next 16 years, then the percent of those students who would be available to enroll at the freshman level is also going to decline.

The schools then will be faced with an alternative of either letting enrollments at the freshman level slide or trying to keep them constant, which means they are going to be dipping down deeper into the applicant pool, and there have already been numbers of articles written about the possible problems we have at the secondary level in training technical people to succeed at the collegiate level. So again, there is an erosion that we see taking place that we are very concerned with.

Let me further take a look at the problems we have at the academic level as far as faculty positions in the engineering and science positions are concerned.

This transparency indicates, by discipline, the unfilled positions that currently exist in higher education. You will note that, as you come down through, the percent of positions that are unfilled range from 5.2 percent for civil engineers, civil engineering programs, to a high of 15.8 percent in computer science/computer engineering types of programs.

This represents only the unfilled positions as compared to those positions authorized within the budgets of the higher educational institutions.

If you further take a look at that by rank, you note that the biggest impact on faculty vacancies and the inability to fill those vacancies occurs at the assistant professor rank. Of those positions, 20 percent currently authorized for assistant professors are vacant, and this then again compounds the ability of higher education to react to the changing needs, the increasing needs, of technical education.

The bottom portion of this graph represents the percent that the authorized positions represent of the actual needs of the program to put it back at a level of quality that we used to experience in higher education. You will notice that, at the assistant professor level, those positions authorized today only make up 63 percent of the actual needs of the educational institution.

This transparency, I think, will show that discrepancy a little more clearly. The red portion represents all of the authorized positions in higher education in the engineering science areas. The white portion at the top is those additional faculty positions needed to raise our quality back up to what it was before these tremendous enrollment increases but yet are not authorized positions.

So you can see that all through the engineering educational ranks, we have a serious problem in faculty staffing for educational education.

Now, we further took a look at the actual breakdown of these figures by employer to see exactly where the engineers and scientists are employed and in what numbers. We found, at the baccalaureate level, that 64 percent of the engineering students are employed in business and industry; 9.3 percent in education; 7.4 percent in State and local government; and 4.8 percent in Federal Government.

At the master's level, 56 percent of the candidates were in business/industry; 17.4 percent in education; 7.7 percent in State and local government; and 6.8 percent in Federal Government.

At the doctoral level, 60 percent of our doctoral students were employed in the business/industrial sector, as compared to 28 percent in education and 12 percent in Government.

Now, we maintain an annual study on what is happening on the campus as far as supply and demand are concerned. To give you a further indication of the imbalance in supply/demand, our study this year has found that if you take a look at the offers being made to baccalaureate students as they graduate by all employers, we have found that 51 percent of the offers that have been made so far this year have been made to engineering and science graduates, which comprise only 8.4 percent of the graduating class.

To give you a comparison to that, the humanities and social science majors comprised 28 percent of the graduating class. They received only 5 percent of the offers so far. So you can definitely begin to see that it is industry and business that are the prime employers of technical manpower and that there is a serious imbalance that is currently existing in the supply and demand from that sector.

I would like to make just a few comments about the quality, and I would like to preface my comments first by saying that I have not only been a student of higher education; I have also been a faculty member and also an administrator; and I believe very, very strongly in our educational system in this country; and I believe that the quality in higher education in this country is par excellence. But yet I also believe very firmly that we are on the threshold of some real problems in that quality unless something is done and done very soon.

At the present time, we have had a student enrollment increase in the last decade that has approximately doubled. At the same time the student population has been doubling, the number of faculty positions and the increase in faculty positions went up by only 10 percent. This means, then, that the faculty-student ratios have become very seriously pressed over the last decade.

When you lower the number of faculty in relation to students, several things have to happen, or combinations of these things. Larger class sizes have to result. You also get a situation where, due to faculty shortages, you begin to reduce curriculum and curriculum offerings, which leads, then, to the quality of the degree itself.

You also have to reduce areas of research and innovation simply by overload on faculty; the faculty can only do so much. You have to increase the use of graduate assistants in the educational process, which means you have to use individuals who do not have the experience base nor the educational base of your full-time faculty, and they are the ones, then, that are imparting the educational program to the new people and thus, again, there is an impact on overall educational quality.

You have an upward inflation in salaries. The reason that the unfilled vacancies at the full professor level were as low as they were is because there has been a good movement from industry to education of individuals taking early retirement, moving out of the industry/business ranks in the research/technical areas, and assuming full-time faculty positions.

Due to the experience base of these people, they generally come into the academic institution at the associate and full professor levels tenured. That means the salaries are much higher. You are putting very expensive people in. That pushes your average salaries for the total faculty upward.

The vacancies occur in the assistant professor ranks, which are your lower salaried positions, and thus again, there is a very heavy economic problem for the schools to meet. They can find experienced faculty; they cannot find inexperienced faculty.

We also see, due to the faculty crunch that I have tried to describe, a decrease in the overall quality of facilities and inadequacy in the equipment used for both the educational mission as well as the research mission, simply again a matter of budget.

If you have to factor more dollars into salary, you have less to put into facilities and equipment. One study has indicated that 25 percent of all the equipment now in higher education is obsolete and inadequate for doing any level of research that might be undertaken.

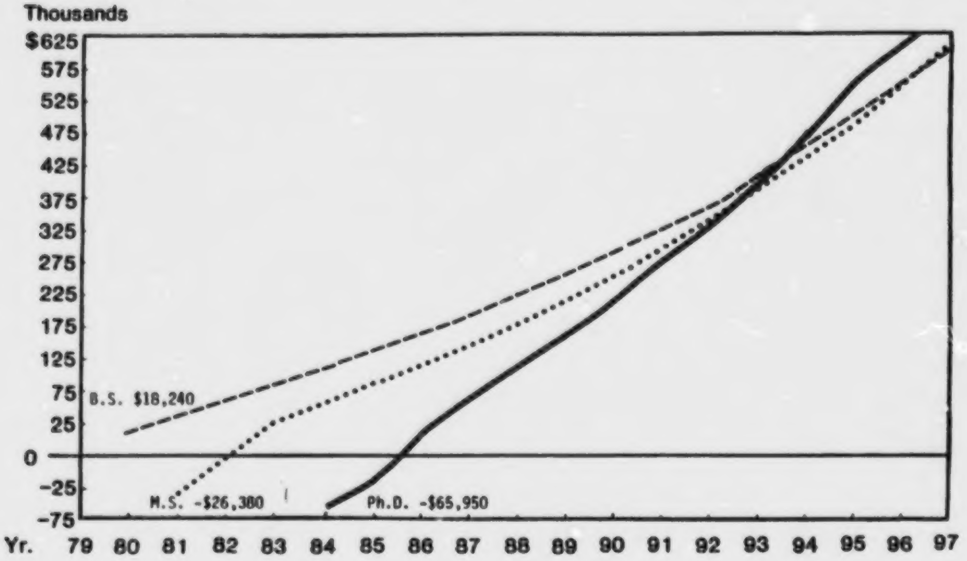
I think another factor of the quality might be if you take a look at the Accreditation Board for Engineering and Technology. Between the year 1978 to 1983, they awarded 50 percent fewer full 6-year recognitions of engineering programs. During that same time period, the number of programs that were not accredited almost doubled. Again, that is a reflection on the ability of our educational system to meet the needs of society due to the some of the problems I have described.

Now, how do we go about trying to get more students to move through the educational process and assume some of these faculty positions? One study that was recently done indicated that of the students currently enrolled in graduate programs, less than 20 percent of them indicated that their goal was teaching. That means the rest of them are looking at other types of career paths.

I think one of the basic problems that we are facing is an economic problem. I had my staff take a look at this and give me a projection as to what the economic situation would be for three students of equal quality, all graduating at the baccalaureate level in 1979. Student A goes out and goes to work immediately in industry. Student B goes on for a master's degree. Student C goes on for a doctoral degree.

Chart 1

Cumulative Earnings by Degree Level



SOURCE: College Placement Council

The yellow portion above the dotted line, the barred line, indicates that baccalaureate major that went out and went to work. The first year his salary back in 1979 would have been $18,240.

What we did was inflate that salary by the actual percentages we obtained from our employer members, and we accumulated earnings, and that is how the curve goes up. The second year, he goes up by another $18,240 plus whatever the salary increase was that that individual would have received, and then each subsequent year he goes up again.

The dotted line, the second line in, represents the master's, the student that went on for a master's degree. You will note that during that 2-year period of time to get the master's degree, he also incurred a debt load of $26,380, which means he starts from a negative position as compared to the student that went to work right out of the baccalaureate program.

We did the same thing. We started them at exactly what the average starting salary was for a master's student, and then we continued to accumulate earnings as reflected in the graph.

The solid bar is the student that goes on for the Ph.D., and there we made a calculation based on information that is currently available, standard information, and we found that the typical Ph.D. candidate would obtain probably a $65,950 debt load in obtaining the degree and thus is starting from a much deeper hole as far as salary accumulations.

You will notice that, based on the very highest starting salary—these are not academic salaries we are talking about; we are talking about industrial salaries. We started this Ph.D. student out of his program at $41,500. That compares to an average assistant professor's salary of $26,400.

So what I am depicting here is the most optimistic payout of a Ph.D. degree. You will notice that it will take this individual out until the year 1994 to even break even with the student that left at the baccalaureate level.

This assumes that there is no peaking in salaries, which I do not think is an accurate assumption. These salaries would peak out there. Consequently, they probably would never cross. The baccalaureate student probably would stay ahead economically as compared to the master's and the doctorate. Now, that is one of the problems of trying to get students to go on and pursue a doctoral degree and thus become part of our research and teaching base.

Other factors have cropped up, and this came from a study of engineering education which said that of all schools, 71.8 percent of the students indicated that one of their two prime reasons for not going on in graduate study was insufficient funding to obtain that degree. I think, again, if you look at the cost of that master's degree and the cost of the doctoral degree, you can see where the students are coming from.

Chart 3

Factors* Limiting Ph.D. Product, Fall 1983

	PUBLIC SCHOOLS	PRIVATE SCHOOLS	ALL SCHOOLS
Insufficient Funding for Graduate School Support	71.8%	71.9%	71.8%
Insufficient Number of Qualified Candidates	48.2	53.1	49.6
Limitations on Size of Graduate Stipends	51.8	37.5	47.9
Insufficient Facilities and Space	18.8	21.8	19.7
Insufficient Qualified Faculty	7.1	9.4	7.7
Other	3.5	3.1	3.4

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*Ranked either first or second in importance.

Source: Engineering Education

Another reason is insufficient number of qualified candidates, limited size of graduate stipends, insufficient facilities and space, and insufficient qualified faculty. These were the reasons the students gave for not moving on.

Another compounding factor I think we have in our graduate program is the percent of foreign nationals that are currently making up the graduate class. This line represents the percentage of U.S. students in graduate student populations in engineering in the fall of 1983.

You will notice that of the teaching assistantships, 56.5 percent are in the hands of U.S. citizens, which means, consequently, roughly 43.5 percent are being held by foreign nationals. In the research assistantships, 57.3 percent are in U.S. citizens' hands, and so forth.

Foreign nationals are being very actively recruited. The higher educational community understands the problems of declining enrollments, so many of the institutions are overseas right now recruiting students very aggressively, and thus we expect the numbers of foreign nationals in our higher educational population to continue to go up.

This represents the distribution of those foreign nationals, and you will note that the heaviest distribution is in the engineering and mathematics area. At the present time, 56 percent of the math students are U.S. citizens; 32 percent of them are foreign nationals; 12 percent did not respond on the survey.

In the engineering ranks, 43 percent of the respondents were U.S. citizens; 51 percent were foreign nationals; and 6 percent, unknown.

This last year, we awarded in this country more doctoral degrees to foreign national students than we did to U.S. citizens. The reason I raise this is simply, if we are facing a faculty shortage and the schools are seeking to try to fill positions, and the available doctoral candidates from which to select are predominantly foreign nationals, then that becomes the source that one must use, or one must leave the position unfilled.

I am not trying to indicate that these foreign national students are not excellent academicians—they most certainly are—but in many cases, English is a secondary language, and thus the students that we talk with indicate that sometimes they must sit in classrooms where they really cannot understand the faculty member, and thus, again, this goes to the quality of the educational program.

So those are some of the problems that we have uncovered that we would like to share with you. I don't want to stop without indicating that there are some things that I think can be done, and we would like to make some recommendations.

Briefly, a couple of the things that we would suggest that one might look at to improve this whole supply and demand of manpower are to increase the support that mathematical and science education receives at the secondary level so that the quality of the educational programs that flow from the secondary level to the higher educational level will be such that the maximum numbers of students will be available, and thus the classes will be filled with individuals who have a high probability of completing the programs.

We also feel that there is additional financial support required at the student level for both graduate study and undergraduate study, especially leading into the areas of research. We must try to uncover early on those individuals who are highly motivated and skilled in the areas of research and allow them as baccalaureate students to get into the research activity, to cultivate a taste for it, and thus to overlook the economic problems of graduate study and move on simply because of self-value. We also would suggest that we take a look at ways of recognizing teacher excellence and to encourage individuals to look at teaching as a viable career path.

Another suggestion we would offer is simply that the whole area of facilities, equipment, and research capability in the higher educational level must be addressed, must be upgraded and brought up to date, so that it at least is comparable to industry, or as close thereto as possible. With tremendous discrepancies in the research capability between higher education and industry, again, students tend to then move out of the higher educational ranks and into industry simply because they do not have research capabilities to meet their needs in the higher educational institutions. So that must be addressed.

And, finally, we would highly encourage that ways be found to not only maintain but to increase the incentives to the private sector to encourage them to become a very pro-active part of building and maintaining the quality of higher education. Presently the private sector spends more dollars nationally on education than the entire higher educational budget in this country. With the bulge coming through at the mid-management ranks, the need for continuing education is going to increase even more dramatically, and thus the only people that can really pick that up is the private sector.

We do not see the public higher educational institutions being able to account for all of the continuing education needs in order to make this big bulge of people who are approaching obsolescence as far as technical training a viable part of our future manpower needs.

So these are some of the things that we would like to suggest, and again, I thank you very much for the opportunity to appear here, and we would be more than happy to provide any additional information you might require.

[The prepared statement of Mr. Smith follows:]

PRESENTATION TO THE SCIENCE POLICY TASK FORCE OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

by

Jesse M. Smith, Jr.
Executive Director

College Placement Council, Inc.
62 Highland Avenue
Bethlehem, Pennsylvania 18017

April 23, 1985

On behalf of the College Placement Council, Inc. (CPC) and the nation's colleges, universities, and major employing organizations, I want to thank you for inviting us to be a part of the very important deliberations being undertaken by your Committee. Since CPC is the national professional organization linking higher education and the world-of-work, we are very concerned with the supply and demand issues for scientists and engineers and the adequacy and relevancy of educational programs to meet the needs of industry and society in the future. Our comments will be directed primarily at those manpower issues included in your agenda. Specifically, we wish to address the following areas:

- Supply of and demand for science and engineering manpower;
- Adequacy of scientists and engineers in terms of both the level of degree received and the quality of educational preparation;
- The role of federally funded educational programs in meeting manpower needs for scientists and engineers in the future;
- The role of the private sector in helping to provide the technical education required to meet future needs; and
- The impact of foreign nationals in the total manpower picture.

SUPPLY OF AND DEMAND FOR SCIENCE AND ENGINEERING MANPOWER

One does not need to read very many studies to realize that a considerable discrepancy exists where projections of supply and demand for scientific and engineering manpower are concerned. The National Science Foundation forecasts considerable shortages in the supply of certain science and engineering manpower, while the Bureau of Labor Statistics believes that supply and demand are roughly in balance. We realize that projecting supply and demand is not an easy task, but we do feel that there are certain issues that should be considered when addressing the subject.

To begin to understand the supply side of this equation, we must consider several critical factors:

- the shortage of qualified faculty at the secondary level;
- the shortage of faculty at the college and university level; and
- changing demographics.

The shortage of qualified science and mathematics teachers at the secondary level is, in many cases, limiting the competency of students in these academic areas.

Those students who do have the academic background and express an interest in pursuing engineering at the post-secondary level are being turned away by university engineering departments because of critical faculty shortages. Student engineering enrollments have doubled in the last decade, but the number of engineering faculty members has increased only 10 percent over the same period of time.

Jobs in the private sector are often more attractive in terms of salary, creativity and professional standing, than are teaching positions. It has become increasingly difficulty to attract U.S. citizens with Ph.D.'s to academia and a sufficient faculty supply is essential both to the quality and the quantity of engineering graduates in this country's future.

Changing population demographics point out that there is and will continue to be a decrease in the number of traditional college-aged students. If the potential pool of college applicants in the 18-year-age range is going to decline, then the numbers who would be qualified to study the technical disciplines would also decline, further impacting the freshman class in engineering schools.

At this point, one of the reasons that enrollments have not begun to drop significantly is the influx of women, foreign nationals, and nontraditional students who have more than made up for the decline in the traditional college population.

Industry attitude also has an effect on the potential supply of engineers available for graduate study. Many of the employers we deal with have indicated that the value added by a master's degree does not justify the price differential. Thus, they are more desirous of hiring new bachelor's degree recipients and training them in specific disciplines and job specialties while on the job. This increases the demand at the bachelor's level, which causes the average starting salary to increase faster than the rate of inflation. The result is that students cannot justify, economically, going on for a master's and/or doctoral degree. (See Chart 1)

On the demand side, let us look first at the current situation. In the July/August 1984 issue of Manpower Comments, the industrial sector was employing 52 percent of the scientists and 77 percent of the engineers. Educational institutions employed approximately 25 percent of all scientists and 5 percent of the engineers. It becomes rather obvious that business and industry is the largest consumer of scientific and engineering manpower.

Based on the Spring 1984 Occupational Outlook Quarterly, approximately 1,204,000 engineers are currently employed. By 1995, there will be an additional need for 584,000 engineers, or an increase of 40 percent. Within specific engineering disciplines, the projected increase in manpower between 1982 and 1995 ranges from 22 percent to 65 percent, excluding computer engineering and computer science specialties, which are projected to grow in demand at an annual rate of approximately 6 percent--which could mean a need for 78 percent more computer specialists by 1995.

Because we are dealing with a somewhat inflexible supply, reactions to changes in demand can be difficult. One step that could ease potential shortages would be more effective utilization by business and industry of the current supply of engineers. Many older engineers are not being fully utilized in their jobs and could take on many of the new jobs being created if given the incentive or the proper retraining.

But to assure that the demand for engineers can be met in the future, a comprehensive plan should be adopted that will provide a constant flow of qualified graduates, regardless of upswings or downturns experienced in the marketplace. We should try to control enrollment fluctuations that we have experienced in the past due to the cyclical nature of the economy and the job market. Technology is here to stay. Engineers will be an integral part of that expanding technology and demand for them will continue regardless of economic cycles.

(See Chart 2)

ADEQUACY OF SCIENTISTS AND ENGINEERS IN TERMS OF THE LEVEL OF BOTH DEGREE RECEIVED AND THE QUALITY OF THE EDUCATIONAL PREPARATION

Given the scenarios described earlier relative to the basic supply/demand question, one must conclude that the ability of higher education to provide adequate numbers of new traditional graduates is suspect.

We are moving rapidly from the "industrial society" to the "informational society," and simultaneously facing major changes in the infrastructure of corporate America. One major impact of this transition is that many of the disciplines and specialties that existing science and engineering personnel possess are disappearing and whole new disciplines and specialties are appearing. While this whole transition is occurring at a fantastic rate, higher education does not have the capacity, budget, or faculty base to change at the same rate. Consequently, higher education is poorly positioned to provide the retraining that the baby boom generation requires to be a viable solution to the demands of both the near and distant future.

Current studies indicate that fewer than 20 percent of students going beyond the bachelor's level are doing so in order to teach. The potential supply of engineers available for graduate study has been affected by the issues raised in the supply section. Some of the other factors that limit Ph.D. production are: (See Chart 3)

1. Insufficient number of qualified applicants.
2. Insufficient number of qualified faculty.
3. Insufficient funding for graduate student support.
4. Limitations on graduate stipends.

Possibilities that may be considered are:

1. A change of attitude by industry that would encourage advance study.
2. Incentives to attract and retain quality faculty.
3. Increased financial support for graduate students.
4. An increase in expenditures on research facilities and equipment to provide state-of-the art research environments.

The issue that we addressed in the beginning of this presentation touched on the critical faculty shortage now being experienced in many science and engineering programs. While the rate of faculty vacancies in authorized positions has dropped to approximately 8.5 percent, if one combines existing faculty vacancies with the faculty shortage, based on the need for maintenance or restoration of quality, the overall shortage of engineering faculty is nearer 23.3 percent. (See Chart 4)

Increased teaching loads. crowded classes, increased reliance on part-time faculty members and on teaching assistants, a decrease in research time, obsolete equipment and outdated facilities cannot help but impact the quality of education.

Another concern is the growing specialization of engineering curricula which has lessened the awareness of how technological decisions affect economic and social systems. A commitment to broad-based education is critical.

Science and engineering education must be a high priority of the federal government if we are to assure the continuing leadership role of this country in today's exploding technological advances.

THE ROLE OF FEDERALLY FUNDED EDUCATIONAL PROGRAMS IN MEETING MANPOWER NEEDS FOR SCIENTISTS AND ENGINEERS IN THE FUTURE

The role of promoting research via funding is still meaningful, but the needs go well beyond research funding. Basic facilities and equipment to support both teaching and research are in great need of modernization. A NSF study showed that 25 percent of research equipment at the university level was obsolete. Due to faculty shortages, substandard facilities and equipment programs, the Accreditation Board for Engineering and Technology awarded full six-year recognition to 50 percent fewer engineering programs during the years 1978-83. Those not accredited almost doubled.

Given similar problems at the secondary school level and the declining enrollment picture for the next 16 years, again one must raise serious questions about the quality of our technical delivery system for the foreseeable future. In order to catch up, federal programs must be devised to help in the acquisition of facilities, equipment, and faculty. Federal incentives must be provided so that the private sector will also help to build the quality of academic programs. Issues that need to be addressed by the Federal Government are:

- Support of increased mathematical and sciences education at the elementary and secondary levels to prepare students for engineering education.
- Financial support programs for students choosing graduate study in sciences and engineering.
- Programs designed to reward teaching excellence.
- Rehabilitation of the nation's research facilities and equipment--directly through increases in funding and indirectly through an extension of the valuable tax incentives that have encouraged industry

to donate equipment to the campuses. Without this effort universities will not be able to conduct pioneering research or to attract the best faculty and students.

- Change in antitrust laws to allow jointly research on projects too expensive for a single company to undertake alone.

THE ROLE OF THE PRIVATE SECTOR IN HELPING TO PROVIDE THE TECHNICAL EDUCATION REQUIRED TO MEET FUTURE NEEDS

A decline in federal support for basic research and research training has led many universities to seek funds more aggressively from industry. Many companies are responding to these new opportunities with large grants of equipment and money. Business-run educational programs have been created as U.S. corporations try to fill the gaps left by traditional colleges and universities. Overall, nearly $6 billion a year is spent on corporate education with an enrollment of approximately 8 million students. At least 18 corporations are awarding academic degrees. These corporations are or soon will be accredited. Corporate classrooms have established an academic legitimacy that rivals traditional institutions of higher learning. Industry also provides support in the form of gifts, scholarships, co-op programs, internships, joint sponsored research, faculty exchange programs, key executive programs and American Electronic Association faculty development programs. Industry could be encouraged to take on greater numbers of faculty and students in the form of co-op programs that would expose them to more current technology and applications, while easing the enrollment/faculty loads in the institution.

New means need to be found to enable cooperative arrangements between groups of employers and institutions. Shared research funding and facilities could be one example.

To increase the flow of U.S. citizens through graduate programs, new systems must be devised to assist in the identification of talented young people who are motivated to teach and do research, and outreach programs, funded by both the public and private sectors, must be provided to encourage those qualified to pursue doctoral degrees.

IMPACT OF FOREIGN NATIONALS ON THE TOTAL MANPOWER PICTURE

Enrollments of non-U.S. citizens in higher education increased dramatically during the 1970's. Although the rate of increase has declined in recent years, many U.S. colleges and universities are aggressively seeking students abroad to combat decreasing U.S. student enrollments.

Foreign students already dominate some fields of graduate study. In 1983, foreign students received 54 percent of U.S. engineering doctorates. (See Chart 5)

With domestic graduate student enrollments low, a strong foreign student body is one short-term answer to keeping the classrooms and laboratories full. In order to avoid reducing engineering enrollments because of current faculty shortages, one alternative that could be looked at would be greater utilization of foreign doctorates, although that often creates a new problem of language difficulty and an inability of some students to understand the message being delivered. Greater use of foreign doctorates also has a negative impact on the ability of the school to obtain defense contracts which would help keep faculty, students, and curriculum on the cutting edge of technology.

In 1982, 18 percent of all U.S. engineering faculty were foreign, and there is every reason to believe that this trend will not only continue, but that the percentage of foreign nationals will increase unless something is done to encourage U.S. citizens to pursue graduate level studies and select teaching careers.

Many employers are precluded from hiring foreign nationals because of excessive red tape and/or security reasons.

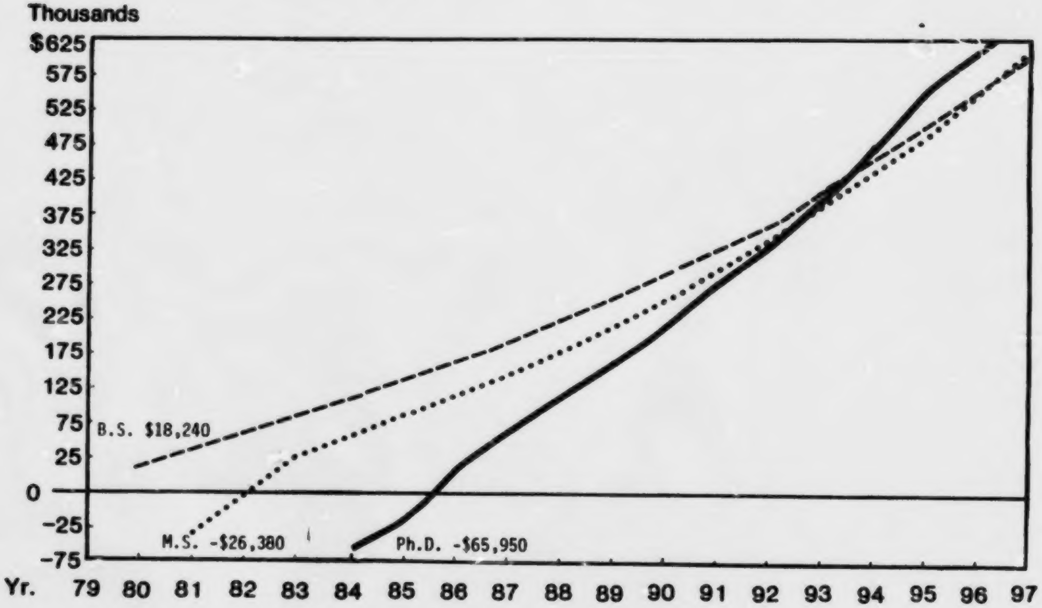
Based purely on need for traditional U.S. citizens to fill entry-level positions in the sciences and engineering areas, we are looking at an increasing imbalance in supply/demand.

CONCLUSION

We hope that we have provided some insight into the scientific and engineering manpower issues this task force is addressing.

Chart 1

Cumulative Earnings by Degree Level



SOURCE: College Placement Council

ANNUAL AND CUMULATIVE EARNINGS BY DEGREE LEVEL

YEAR	BACHELOR'S	MASTER'S	DOCTORATE	ANNUAL %[1] INCREASE
1979	Year of Grad.			
*1980	$18,240			13.5%
*1981	20,702 (38,942)	Year of Grad. -$26,380**		10.4
1982	22,855 (61,797)	25,656 (-724)		6.1
1983	24,249 (86,046)	27,221 (26,497)		3.2
*1984	25,025 (111,071)	28,092 (54,589)	Year of Grad. -$65,950**	4.3
1985	26,101 (137,172)	29,300 (83,889)	41,160 (-24,790)	6.0
1986	27,667 (164,839)	31,058 (114,947)	43,630 (18,840)	6.0
1987	29,327 (194,166)	32,921 (147,868)	46,248 (65,088)	6.0
1988	31,087 (225,253)	34,896 (182,764)	49,023 (114,111)	6.0
1989	32,952 (258,205)	36,990 (219,754)	51,964 (166,075)	6.0
1990	34,929 (293,134)	39,209 (258,963)	55,082 (221,157)	6.0
1991	37,025 (330,159)	41,562 (300,525)	58,387 (279,544)	6.0
1992	39,247 (369,406)	44,056 (344,581)	61,890 (341,434)	6.0
1993	41,602 (411,008)	46,699 (391,280)	65,603 (407,037)	6.0

Continued on next page

YEAR	BACHELOR'S	MASTER'S	DOCTORATE	ANNUAL % INCREASE
1994	$44,098 (455,106)	$49,501 (440,781)	$69,539 (476,576)	6.0%
1995	46,744 (501,850)	52,471 (493,252)		6.0
1996	49,549 (551,399)	55,619 (548,871)		6.0
1997	52,522 (603,921)	58,956 (607,827)		

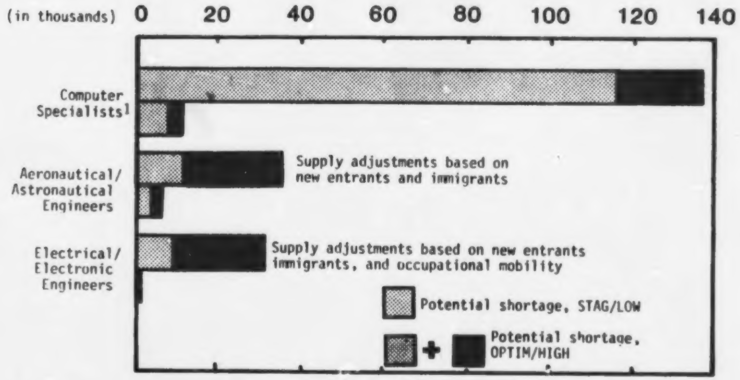
( ) Figures in parentheses are cumulative earnings.

[1] Annual percent increase based on CPI when available. All other years 6.0 percent was used.

*Starting salaries from College Placement Council's Salary Survey report.

**Graduation figures reflect educational expenses incurred based on Peterson's Guide to Graduate Programs in Engineering and Applied Sciences 1985.

Potential Science/Engineering Labor Shortages
1987



[1] Includes both computer systems analysts and programmers.

NOTE: STAG/LOW indicates low-economic growth / low-defense expenditure scenario; OPTIM/HIGH indicates high-economic growth / high-defense expenditure scenario.

SOURCE: National Science Foundation

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Chart 3

Factors* Limiting Ph.D. Product, Fall 1983

	PUBLIC SCHOOLS	PRIVATE SCHOOLS	ALL SCHOOLS
Insufficient Funding for Graduate School Support	71.8%	71.9%	71.8%
Insufficient Number of Qualified Candidates	48.2	53.1	49.6
Limitations on Size of Graduate Stipends	51.8	37.5	47.9
Insufficient Facilities and Space	18.8	21.8	19.7
Insufficient Qualified Faculty	7.1	9.4	7.7
Other	3.5	3.1	3.4

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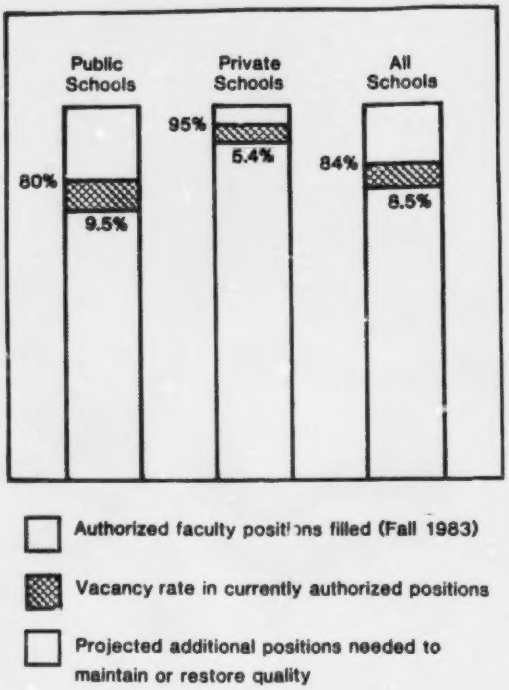
*Ranked either first or second in importance.

Source: Engineering Education

Chart 4

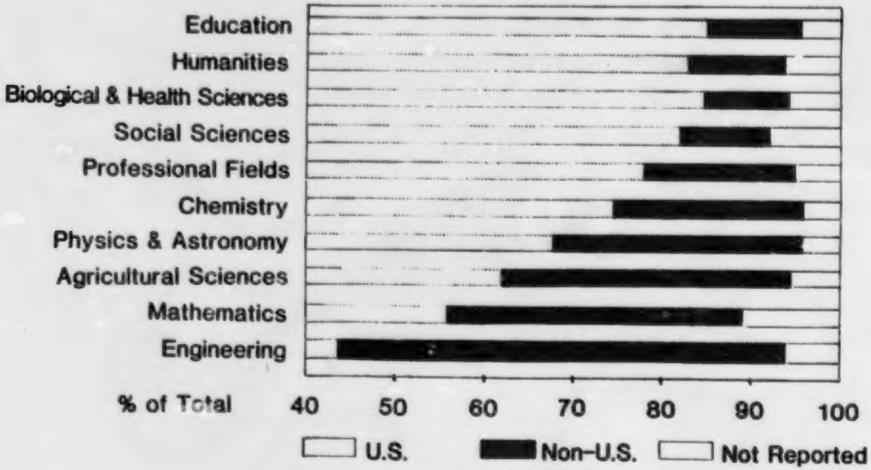
Current and Projected Engineering Faculty Needs (1983 Survey)



Source: Engineering Education

Chart 5

Citizenship of Doctorate Recipients by Field, 1983



Source: National Research Council, "Doctorate Recipients from United States Universities," 1973 and 1983 Summary Reports.
Higher Education and National Affairs

DISCUSSION

Mr. **Fuqua**. Thank you very much, Mr. Smith, and it was a very interesting review of the manpower needs.

Some months ago, I and some of the members of the committee had a chance to visit with some of the personnel directors and research administrators in industry, and I inquired about levels of engineers and research people that they had coming, whether they were having a shortage, and they indicated no, they were not. They also further said that the last group of college graduates that were coming on board then were some of the finest that they had ever had, which I thought was a credit to our engineering and our system of higher education. But they said they were not having any trouble recruiting people, that they were getting adequate supplies of those that they needed. I gather that is not your view.

Mr. **Smith**. We service about 2,600 colleges and universities and also about 2,600 of the major employing organizations, and we deal with them on a continuous basis.

There are imbalances in certain specialties. There is probably parity of supply and demand in other specialties. The areas right now where our members are telling us that they have an imbalance and are having difficulty filling positions are in the areas of the computer specialties and also in electrical engineering.

If one looks currently at the areas such as chemical engineering, civil engineering, and mechanical engineering, probably right now they are not having great difficulty in filling those positions. However, we are down this year. We are still not back up as far as the total demand picture.

This year we have found that the energy-related companies are still out of the marketplace. Many of the high technology, especially those in the chip industry, are completely out of the marketplace, and recruiting activity is not back to the levels that it was at 3 years ago. So that also helps in the imbalance, simply by not having as many recruiters in the field.

Mr. **Fuqua**. You also mentioned the faculty. We hear various numbers quoted. I have used the phrase that I have been told, 2,000 vacant faculty positions that we could not get qualified people, not people to fill them but qualified, whatever that phrase is.

I am wondering, is there a difference, because we are keeping—you mentioned two areas, computer science and electrical engineering. But I am wondering if there is a difference between a real need and a simple desire, and maybe the deans or those that are involved in administering engineering programs—and I am speaking primarily in engineering—want somebody maybe that is more research-oriented rather than classroom-oriented, and also, by being that type, they can bring in more money to the school, so therefore they feel as though they don't have quite the qualified faculty that they would like to have.

I don't say this in a critical sense. I am saying it being more of a devil's advocate, because I hear this, and I am wondering, to what extent do you feel this has any truth to it?

Mr. **Smith**. One of the things I think we are caught up in in this country is the transition from the industrial society to one of an informational society, in which we have fantastic changes taking place in the work force as far as the types of specialties and disciplines that are required.

Education will always lag this change. It is always going to be behind. I don't think it will ever lead industry; industry will lead education in this regard. Consequently, the educational programs are heavily designed around an industrial society and the needs of an industrial society, and the ability that the faculty has to make the transition itself, and the availability of new faculty that can lead this transition, I think, is where the real shortage in faculty occurs.

The degree programs are not there to produce the new types of disciplines that we are looking at and will be expecting to build heavily on, and industry is competing more heavily for them than education is capable of competing. So there is, I think, an imbalance in those types of situations. There is an oversupply, yes, in some of the traditional engineering areas, especially if you factor in the people leaving industry that are available to come back to education. But you must keep in mind, also, that those people got their engineering degrees in the 1960's, and they got them with 1960's technology. Now, they have been working in increased technology since then, but in many cases, the reason industry is cutting out large blocks of midmanagement ranks is a change in the whole philosophy of the infrastructure of corporate America and the ability to react to this new technological need of the future.

So many of the areas that are being cut out are areas that they just do not perceive a need for, and that, I think, again gets into this picture of balance as far as supply and demand are concerned.

Mr. FUQUA. Well, it still gets back to the fact that I am concerned that maybe we don't really have the crisis that we have been led to believe that we have, that we do have quite a number of engineering faculty. It may not be the tops—and I am not promoting mediocrity—but, by the same token, maybe it is not quite the depth that we are concerned about now.

We passed a science and math and engineering education bill last year, and that will come up for review next year. We need to be getting some answers, particularly in the budget situation that we are faced with, whether or not that will be reenacted in the next Congress. It was a response to what we generally perceived to be a crisis.

There are then things that tend to point out, maybe it is not as much a crisis as was pointed to, because the system right now is providing—according to a lot of people that I have talked to and asked the question—very qualified, highly qualified and motivated young engineers and scientists, and somehow the schools are getting them through there without closing the doors. And so maybe with the increased enrollment, there will be more attraction for salaries and other amenities that may attract people into education.

But the concern I really had was between that person that was getting government contracts and maybe had an entrepreneurial relationship with industry that could attract a lot of money into the school, versus that person who really knew how to teach.

Again, I am not being critical of deans or administrators of schools. I would probably be the same way. But I am trying to determine if it is as serious as we think it is, and of course, the charts that you have indicate that there is a severe problem. I am concerned that maybe it is not quite as bad as we thought it was, and I may be wrong.

Mr. **Smith**. One of the factors, Congressman Fuqua, that I think has to be looked at and analyzed more deeply is that the enrollments in doctoral programs are swinging more and more predominantly to foreign nationals. As I said, last year, over 50 percent of the degrees awarded were awarded to foreign nationals rather than to U.S. citizens.

If one looks at the ability to do defense research, for example, there are certain limitations as to the kinds of personnel you can place into that kind of situation. Both our employer members and our college members indicate that this is a tremendous problem of hiring the foreign national doctorate, because that then impacts your ability to utilize these people in a full range of activities.

Mr. **Fuqua**. But why aren't U.S. citizens going into doctoral programs? It doesn't mean it is a lack of a school, because we are filling that void with foreign nationals. I have been asked that question before, and I said that I don't find any fault with that. My problem is that we don't have enough U.S. citizens going into graduate school and the Ph.D. programs.

Mr. **Smith**. I believe that is economics.

Mr. **Fuqua**. Now, where are they going?

Mr. **Smith**. They are going right straight into industry.

Mr. **Fuqua**. With a bachelor's degree?

Mr. **Smith**. With a baccalaureate degree. They are going straight from the baccalaureate program into industry at salaries that are even starting, at the baccalaureate level, higher than the average for the assistant professorship position. And they find that when they are in industry, then they have better research facilities to cultivate a research taste and to actually pursue than they would have in the academic side of the picture.

So we find that supply and demand are pushing the U.S. citizen out to work. There is not a demand for the foreign national, so consequently, they come in at the baccalaureate level, there are not job openings for them, and they flow on through, then, into the graduate ranks.

One study last year showed that every foreign national student with a grade point average of above 2.8 percent went on into graduate education, as compared to what you would find at the U.S. citizen level, which would be way, way below that.

Mr. **Packard**. Would the chairman yield on that point?

Mr. **Fuqua**. Certainly.

Mr. **Packard**. Do you know what percentage of the foreign nationals, after they go through graduate school, stay here in our work force and how many go back to their home countries into their work force?

Mr. **Smith**. I have that figure, but I would have to pull it out of some background. If you would like me to, I will be glad to do that.

Mr. **Packard**. I was wondering how competitive they are for those U.S. students that do stay and get their graduate work done.

Mr. **SMITH.** They are competitive at the higher educational ranks because the requirements are not as severe on higher education being able to utilize the foreign doctorate as on industry and business.

I will try to provide that figure for you.

Mr. **SMITH.** Again, any defense-related industry where there is a security clearance situation runs into certain problems hiring foreign nationals. So they are closed out of certain job markets and thus gravitate more heavily to the job markets that are still open to them, of which higher education is a major one.

Mr. **PACKARD.** Thank you very much. Thank you for yielding.

Mr. **FUQUA.** One more final question: How many scientists and engineers in the private sector actually perform basic research as compared to applied research? Do you have any figures on that?

Mr. **SMITH.** The one figure I do have is that for this current year, 75 percent of all R&D activities will be done in the private sector. Only 12 percent will be done in higher education.

Mr. **FUQUA.** Now, is that between basic and applied?

Mr. **SMITH.** It is the entire R&D sector. I would assume it would be, sir. It would be both, I believe.

Mr. **FUQUA.** But you don't have a breakdown between the two?

Mr. **SMITH.** Not with me, I don't.

Mr. **FUQUA.** Do you think you have that somewhere? I would be very interested to get that.

Mr. **SMITH.** We will sure research and see if we can do that.

Mr. **FUQUA.** If you could submit that to us, we would appreciate it.

Mr. **SMITH.** The breakdown—give me that one more time, and I will make sure we get it.

Mr. **FUQUA.** The percentage of basic versus applied research that is carried on in the private sector. Generally, most of the basic research is considered to be carried on in colleges and universities and places of that type, and more of the applied, a higher percentage would probably be in industry. But what would be the percentage that industry performs of basic research versus applied?

Mr. **SMITH.** I will have my staff research it, and if we can get an answer, we definitely will get back to you.

Mr. **FUQUA.** All right. If it is not too much trouble, I would appreciate that.

Mr. **SMITH.** Not at all.

Mr. **FUQUA.** Mr. Lewis?

Mr. **LEWIS.** Thank you, Mr. Chairman.

Mr. Smith, the statement you made in answer to the chairman's question about we have no shortage of chemical engineers and those related disciplines, is this probably a cause of 6 to 8 years ago, with the tremendous impact in the petrochemical area, with the shortages there; that now they have made up their shortages and engineering students were devoted in that direction, away from electronics and those related industries? Is that a possible truth?

Mr. **SMITH.** There is a very serious problem that we have in this country in higher education in that we are so visible to all of the media hype that comes across one's TV and newspapers, and students read this, and they react very seriously to it.

As an example, chemical engineers. The bottom fell out of the engineering market in the early 1970's, as I am sure you are aware. Consequently, enrollments took a nosedive in engineering programs. When that economy hit and the employers quit hiring engineers, enrollments dropped in the engineering schools. When the employers come back in, they are leading education by 5 years, because it takes between 4 and 5 years to get a student through a baccalaureate engineering program. Consequently, the supply side is always lagging demand, or we hit a down demand cycle and we are oversupplied.

Chemical engineers have hit that down demand cycle in the last 3 years because of the withdrawal of the energy-related companies from the job market, and right now we probably are in fairly good shape on chemical engineering. However, those energy-related employers have not been hiring for the last 2 to 2½ years, which means they have got a gap in their human resources pipeline. If they were to turn around economically, they would have to scramble to fill that gap because that would impact them very heavily economically at the midmanagement ranks. So they would create an overdemand picture, and thus we have this cycling going on because of the economy that is swinging to extremes, and engineering is very susceptible to that.

Mr. Lewis. I would like you to broaden just a little bit here your requirements of what the Federal Government needs to do in order to increase the manpower needs for scientists and engineers in the future. Now, you do point out in your presentation a number of areas. Could you be a little more specific in what the actual role of the Federal Government should be and how they should get in step with your proposal?

Mr. Smith. Broadly, I believe the role is on two fronts. One is to assist through resources the maintenance and rebuilding of educational quality in the engineering ranks, but also through incentives to the private sector.

As an example, recently there was great concern. I know, on our members' parts as to what Congress would do with regard to allowing continuing education to be an activity that the employer could undertake on behalf of employees and still deduct it, and that was a big concern. If that incentive were removed, for example, that whole big bubble that is caused by the baby boom group which badly needs reeducation and retraining would be seriously impacted, and that would then fall totally outside of the private sector to the public sector and thus would even compound our problems. So we are suggesting that incentives need to be looked at to encourage participation of the private sector in the manning of educational programs, providing of faculty, providing of equipment and resources of the educational process itself.

For example, if industry would double or triple the use of co-op students, that would greatly impact the quality of education because it would have these students and faculty members flowing through modern, up-to-date research technical facilities and flowing back into education on an altering-semester basis.

That would relieve some of the pressure on the student-faculty ratio at the higher educational institution and make a partnership out of the private sector and the public sector on education. I think there need to be some ways found to try to encourage the private sector to do that, as an example.

Funding, quite obvious; facilities, equipment, research grants funding, but also funding directly to the students to encourage them to stay in higher education, to obtain the credentials that they need, and then to become resources for research, teaching, what have you. So it is a twofold incentive/funding picture.

Mr. **Lewis**. Do you subscribe to the theory that we are rapidly losing our scientific and mathematical types of disciplines and falling behind as far as Japan, Germany, and the Soviet Union are concerned?

Mr. **Smith**. I am afraid I do, sir.

Mr. **Lewis**. What kind of incentive do you feel is required to bring more students and faculty members on a cross-training program into those disciplines?

Mr. **Smith**. Graduate stipends for students at both the master's and doctoral level; the funding of research in higher education to enable more undergraduate students to become directly involved in research so that they awaken an interest, a motivation to do research, and thus possibly stay in the academic ranks.

I think, also, there is the need to find vehicles to enable industry and higher education to work more closely together in joint kinds of projects, or for clusters of industry and clusters of universities to work more closely together, so that the research capability is more equal in the higher educational institution and in the private sector. Right now a lot of people that are motivated to do research are not motivated to stay in the higher educational realm because of the antiquated research facilities and equipment that they have access to or, in some cases, the fact that they do not have access at all simply because of priorities of rank and tenure that keep the junior person more in the teaching ranks and less in the research ranks. And if they are motivated to do research, then they are not going to stay in and teach.

Mr. **Lewis**. Thank you, Mr. Smith.

Thank you, Mr. Chairman.

Mr. **Fuqua**. Mr. Packard?

Mr. **Packard**. We have an oversupply, I think, of physicians, dentists, medically trained people. We have an oversupply of lawyers in this country. We have an oversupply—and I don't just say that. I think there is an actual oversupply; I am not talking about my philosophy of lawyers. [Laughter.]

I spoke about the dentists first. I am a dentist by profession. We have an oversupply of elementary and secondary teachers in this country. We have an undersupply of engineers, science graduates, higher education instructors. Do you think that the normal cycle of supply and demand will motivate some of these that are in oversupply to begin to gravitate toward those in greater need, and do you think that that will become a natural balancing process over time, or do you believe we have to somewhat regulate, through incentives and other procedures, to try to bring about a balance of that supply and demand?

Mr. **Smith**. I know a number of the studies that I have read that indicate that there is not a problem I believe reached that conclusion heavily on the basis that there are oversupplies in some areas that could easily be moved over to pick up the undersupply in other areas. I question the ability to do that, not because individuals would not necessarily be motivated to make that transition, but they would be ill-prepared in many cases to make that transition. You cannot take a person out of a humanities/social science program and put him into a technical program without providing him some continued education to bridge that gap of his own educational base.

The minute you start putting more education load on the system, then you are going to compound the problems we already have. That is one of the concerns we have with this baby boom bulge that is hitting right now and is being greatly displaced. They are going to have to be retrained if we are going to maintain their productivity in the system.

Right now that retraining load is heavily assumed by private industry. I believe that is why the figures say that they are now spending more dollars than all of higher education. It is heavily in the retraining area.

I believe there are some disciplines that, with the proper training and the proper incentives, could be used to meet the shortfalls that we are now experiencing and will experience in the next decade. I think you have to look beyond that, though, and say that again we have cycled through—we went through peak enrollments of the 1970's; now we are hitting a situation where we are going to have 16 years of declining enrollments for the traditional entering freshman student, not the nontraditional student, because they are coming in in greater numbers, but the traditional freshman student is declining for the next 16 years.

We could use that time period to better augment the ability to pick that education up when that cycle changes, and we are now in the postbaby boom generation coming through, or they call it the baby bust generation. They are impacting elementary education. They are going to move right on through, and 12 years down the road, they are going to hit higher education, and we are going to be back in the same place if we don't do something between now and then.

Mr. **Packard**. Thank you, Mr. Chairman.

Mr. **Fuqua**. Mr. Brown?

Mr. **Brown**. I have no questions.

Mr. **Fuqua**. Mr. Boehlert?

Mr. **Boehlert**. Mr. Smith, don't you think we are failing at the elementary and secondary level? That is the area that concerns me so much. The whole orientation seems to be, with young people as they enter our educational system, to assume—society seems to assume—that they are all going to be social scientists or liberal arts majors when they go on to college.

In New York State, we have just gone through a big battle to require 3 years of science and 3 years of math in high school. Aren't we failing miserably? Shouldn't we start way back about third grade requiring it?

It seems to me I read someplace that the Soviet Union has just made a commitment in terms of elementary education level, and they are going to start providing all their kids with personal computers by the time they are in the equivalent of our sixth grade. And yet, in our society—and I am probably a typical example—all the way through grade school, high school, college, some graduate work, and I can't even balance my checkbook.

I mean, I had very little training in math and science. Nothing was required of me. We give youngsters too many electives, too many options. Can you imagine a society giving a credit for high school graduation for driver education? And yet these same youngsters, in their senior year, are not taking any math or science courses. I mean, don't we have to start at the beginning?

Mr. **Smith**. That is why I prefaced my recommendations. The very first one was, we have to increase the quality of the secondary level of education feeding into higher education if we are going to really make any long-term impacts. I agree with you totally on that.

Mr. **Boehlert**. All right. And another area to jump—I asked this question of Dr. Keyworth a few weeks ago, and I was appalled by the answer, quite frankly. As you look at the administration's proposed budget for fiscal year 1986, doesn't it bother you the way funding for the various educational assistance programs is handled? It seems to me that we are going to deny ourselves a lot of the talent that we need in so many disciplines, but particularly in science and engineering, because so many young Americans simply won't be able to afford to go on to undergraduate studies, let alone graduate studies. Haven't we got our priorities sort of screwed up? Shouldn't we be putting more money into those areas?

Mr. **Smith**. Having been a faculty member and an administrator in two different higher educational institutions, I have seen abuses of the system.

Mr. **Boehlert**. Of course.

Mr. **Smith**. There is no question in my mind that, I think, some of those abuses have to be addressed. So I have mixed emotions.

When I see individuals that are using Federal funding not because they need that Federal funding in order to be able to attend education but are simply using it because it is a lower interest rate and thus they can invest their own funds and make more money and thus turn around and pay it off and they have made money while they are going to school, I am not sure that is the proper use.

I would love to see a system that would assure that any student who wants a higher educational degree gets one. That is what I think the system should do. I am not sure our system now is geared to do that.

Mr. **Boehlert**. How do we go about making those changes? Aren't you concerned that if we proceed along the path that Secretary Bennett, for example, has outlined, that we are going to deny ourselves a lot of the best talent that we should have and fully develop their minds? But they are not going to be able to do that because they don't have the resources to do it. Doesn't it bother you?

Maybe I am wrong. You would make me very happy if you would tell me I am 100 percent wrong, or even 90 percent wrong, or even 50 percent wrong. But I just have a very strong feeling that there are a great many young Americans that are not pursuing their education because they simply do not have the resources to pursue their education.

Mr. **Smith**. We know from some of our own work that there are a great many who are not pursuing higher education because they do not have the incentives and the role models to do that. I think that is an equally large problem.

For example, General Motors, to attempt to impact their own future, has developed an educational program that begins down in the elementary school, that says to a family, if your son or daughter is willing to undertake additional math and science work above and beyond their day-to-day educational program and will stay in this program on through, we will provide them a higher educational degree; we will pay their way.

So there is no question that there are indications in the marketplace that the numbers are not flowing through in the rate we would like to see and that some of the problems are financial—they cannot afford to flow on through—and some of them are role models. I think this is a heavy problem, for instance, in our minority areas. You don't have a lot of real strong, publicly visible minority role models in engineering that minority youth, for example, will see and then gravitate on into engineering.

It is a very complicated, complex equation, and it is one that I am sure better heads than mine have contemplated and still have not come up with answers, so I doubt if I could, either.

Mr. **Boehlert**. Then, of course, there is the question of compensation for people who are in education at all levels. That is a problem we have to address.

Are you familiar with what has happened down at the University of Texas? Somebody told me a convoluted story that there were at least 30 chairs endowed for $1 million apiece, and the faculty they are hiring are just being compensated through the annual interest on the investment of that $1 million, so that we have got, at the University of Texas, a number of full professors making $100,000 a year. Is that a trend? Is that a true story?

Mr. **Smith**. I would not doubt it.

Mr. **Boehlert**. They do things in a big way down in Texas. How do the rest of us compete with that?

Mr. **Smith**. I know they are out to become the world's leading computer science higher educational institution, and they are spending a lot of dollars to do that, because we are seeing the impact. They are hiring some very, very good people, and you don't hire them cheaply. You have to compete in an open marketplace to hire those kinds of people. But they are competing and bringing them into that program, so they have a lot of dollars; there is no question about it.

Mr. **Boehlert**. Thank you.

No further questions, Mr. Chairman.

Mr. **Fuqua**. Thank you.

Thank you very much, Mr. Smith, for your contributions here this afternoon.

Mr. **Smith**. Thank you, sir.

Mr. FUQUA. We may have some additional questions that did not come up today that we may submit to you, and we would appreciate it if you would respond.

Mr. SMITH. Certainly.

I will get you a response on that other question, too.

Mr. FUQUA. Thank you very much.

PANEL: INDUSTRIAL RESEARCH MANAGEMENT

Mr. FUQUA. Our next group will be a panel on industrial research management: Dr. Samuel Tinsley, director of Technology Planning at Union Carbide; followed by Mr. William A. Stickel, director of Patents and Licensing, United States Steel Corp.; and Dr. Keith W. McHenry, vice president of Research and Development, Amoco Oil Company.

Dr. Tinsley, we would be glad to hear from you first.

Dr. TINSLEY. Thank you, and thank you for this opportunity to be here today and to contribute, hopefully, to your review of American science policy. There is a very rich literature on the subject. However, in view of the recent structural changes in many sectors, particularly, of our manufacturing industry, it seems like an appropriate time for a comprehensive review and for possible selection of new directions.

I am currently president of the Industrial Research Institute. The IRI was founded in 1938 under the auspices of the National Research Council. It is an association of some 270 companies, and I believe we estimate that we perform about 85 percent of the industrial R&D that is done in the United States.

The IRI was incorporated in the State of New York in 1945 as a nonprofit 501[c]6 organization, whatever that means, and our mission is to enhance the effectiveness of industrial research. I will not enumerate the specific purposes of the institute. They are published in our annual report, and I hope you will have a chance to scan that.

We will address the seven topics that it was suggested that we make statements on in the order in which they were listed, and I think Bill Stickel draws the first duty.

STATEMENT OF WILLIAM A. STICKEL, DIRECTOR, PATENTS AND LICENSING, UNITED STATES STEEL CORP., PITTSBURGH, PA; ON BEHALF OF THE INDUSTRIAL RESEARCH INSTITUTE

Mr. STICKEL. Mr. Chairman, honorable members of the House Science Policy Task Force, and guests: I am Bill Stickel of Pittsburgh, PA. Currently, I am the director of Patents and Licensing for United States Steel.

Dr. Harry Paxton, our vice president of Corporate Research and Technology Assessment, was scheduled to testify before you today but had an unavoidable conflict and has asked me to extend his apologies.

I am pleased to appear before the task force today to help present industry's view of Federal science policy. Specifically, I will comment on the issues related to levels of research funding and management of that funding. Recommendations for change will be interjected where appropriate.

I would like to submit the full written statement for the record, but I will extract from it here for the sake of brevity.

Let me first review industry's views on funding levels and trends. You, of course, are familiar with the data, but a summary will help set the stage. My source is the Battelle Memorial Institute, which has a very comprehensive forecast and analysis of probable levels of R&D expenditures.

Battelle's forecast predicts a total R&D expenditure in the United States of $107.3 billion during the calendar year of 1985. This is an increase of 10.6 percent over the estimates of what their final accounting will establish was spent in 1984.

Federal funding in 1985 is expected to be about $48.7 billion, or 45.4 percent of the total R&D funding, which represents an increase of $4.4 billion or 10 percent from 1984. Industry funding in 1985 will see 51.3 percent of the total for R&D or about $55 billion. This is indicative of an 11.4-percent increase, or $5.63 billion.

Estimated sources of funding for R&D by broad industrial class are found in the Battelle report and can briefly be summarized by stating that other than aerospace, electrical machinery/communications and rubber products, most industry R&D will be paid for primarily by industry funds.

The Federal Government will fund 32.2 percent, while 67.8 percent will be funded by the industries themselves. The Federal Government was the primary source of R&D money from 1953 to 1979, but has since experienced a gradual decrease when compared to the corresponding increase of industry funding. Industry is now the major source of R&D funds and also the primary performer of R&D.

Federal funding for R&D available through the awarding of contracts, through various agencies, results in much important research being performed that might not otherwise be affordable to industry by itself. Historically, the results of Government-sponsored research were owned by the Government and were available in principle to all interested parties.

Theoretically, this was intended to result in the most rapid dissemination of new developments. But in reality, the spread of new technology is often better served by allowing the Government-funded proprietary technology to revert to the company that developed it and which therefore has the technical expertise to best transfer the technology.

More recently, the Government has made considerable progress in allowing patent rights to accede to the developer. Sometimes the company is required to pay back Government developmental money with profits earned from the sale of the technology, and we think that is a fine idea.

With regard to the management of the funding, levels of funding, of course, are guided by industry's view of the ability to increase profits through the future use and/or sale of the developed technology and simultaneously of governmental regulatory constraints that limit savings, sales, or market share.

Internal company policies which govern the selection of R&D projects and levels of internal funding vary dramatically across industry, as can be seen by even a brief perusal of the percent of sales invested by different groups. These variations are due to a number of reasons, including differences in the life cycle of products, capital requirements for implementation, and market demands.

Generally, recommendations of R&D management are developed in an iterative fashion. Input is sought and received from all areas of a company expected to provide funding, manpower, expertise, facility space, or equipment, and, of course, to eventually sell the end product. The expense of performing R&D plus often a long turnaround time to payoff requires that all funding commitments be made typically at a high level, usually by the CEO and/or the board of directors.

Cost-benefit analyses are part of every project, and many different factors are examined. Government legislation, regulations, taxes, tariffs, and the general economic climate are always examined carefully. In some cases, this may include State and local legislation.

In a recent issue of *Research Management,* Joseph M. Carlson states that, at least for high technology, initiatives and regulatory matters will be most often on the State rather than the Federal level. He also predicts that soon larger companies could be dealing with the equivalent of 50 EPA's, 50 OSHA's, and 50 Consumer Product Safety Commissions. This will mean that long-range R&D decisions will have further complications as they try to incorporate the need to satisfy these pluralistic Government entities.

R&D funding decisions have always been influenced by input from corporate planning departments and commercial research branches supplying information on competition and market. Where Government is the customer for the products of new technology, it can directly influence industrial R&D decisions, but otherwise project choice must be market-driven and, of course, responsive to what the budget will bear.

Academic institutions and some national laboratories have always performed basic, fundamental R&D that is frequently brought to fruition rather slowly. Increased Government funding of these institutions could support more fundamental research from which, in principle, the entire industrial community can profit. But increased funding per se is not necessarily the most appropriate route.

In line with the often necessary requirement in industry to do more with less, we believe that an examination of the effectiveness of current programs and, more particularly, the way in which developments are transferred to potential users, can lead to significant improvements with little or no increase in expenditures.

The Federal Science and Technology Committee of the Industrial Research Institute has begun a study of ways in which research supported by the Federal Government can, with suitable input at the planning stages, produce important benefits to large areas of the commercial economy. It has been well established that fallout from defense-sponsored research has enabled the United States to maintain international competitiveness in fields such as aerospace, telecommunications, and computer science.

Two recent reports—the Presidential Commission on International Competitiveness and the Packard Report on Federal Laboratories—have urged that we look for ways to produce similar effects in other industries which, for whatever reasons, have been having difficulty in maintaining leadership positions in the international trade arena.

Also, some years ago, the Federal Science and Technology Committee of IRI began a program with Federal laboratories to acquaint them with some areas of industrial research interest and, in turn, to become more familiar with programs in the laboratories.

Industry is also interested in the research performed in academic institutions which are considered for project funding when industrial R&D money is allocated. Currently, there is about 7 percent of university research supported by industry. We expect an increase in that area.

In selected cases, both academic and industrial researchers can benefit from working together on joint programs. There are some caveats: First, a complete understanding of the goals and objectives of a joint industry-university effort is paramount. Two diverse motivations for doing research—knowledge-driven from the university and problem-solving oriented from the industrial enterprise—can lead to difficult problems and must be reconciled at the outset.

Second, the question of ownership of intellectual property resulting from the joint effort must be resolved. The commercial protection and exploitation are critical to the profit orientation of industry, and the need to publish is critical to the university; the two often clash. Neither of these problems is insurmountable but must be recognized.

It is our belief that both industry and Government will jointly have to find ways to utilize R&D effectively in the coming years to keep the United States in the forefront of the technological age.

We also believe that even in these times of massive Federal deficits and excessive red ink in industry, the dollar spent on R&D is a dollar invested in the future economic stability.

Most industries will have to change to more strongly link R&D departments to other corporate decisionmaking areas so research is better planned and managed. More market, academic, and political awareness will be needed to compete effectively, along with a willingness to look into new ways of doing business such as joint venture cooperative research and perhaps contracting out certain research activities.

Government's role should perhaps change, also, to allow a greater emphasis on providing the atmosphere and environment most likely to encourage R&D investment, rather than to set up a national policy which could result in attempts to manage and control commercial R&D choices.

This implies a favorable tax climate with special R&D tax credits, new intellectual property legislation, continuing less stringent interpretations of antitrust law, new depreciation allowances, a climate for a more profitable interaction between national labs and universities and industry, and efforts to keep fair access to domestic and foreign markets.

Along these lines, a proposed project by the Industrial Research Institute's Federal Science and Technology Committee will study the need for appropriate linking mechanisms between industrial research, the Federal Government, and Federal research establishments. Perhaps some of the necessary interactions will be developed there.

To summarize, many features of Government-industry interaction are much better than they were only a few years ago, but continual intensification of international competition does not leave either group in any way self-satisfied.

We commend this committee for recognizing the important of science and technology and, by causing us to review the existing situation, to make us both continue our search for effective ways of using our very considerable research expenditures to maintain our Nation's viability.

Thank you for listening. If there are any questions, I would be pleased to try to provide further information to you.

[The prepared statement of Mr. Stickel follows:]

STATEMENT BY

H. W. PAXTON

AND

W. A. STICKEL

ON BEHALF OF THE INDUSTRIAL RESEARCH INSTITUTE

FOR THE HOUSE SCIENCE POLICY TASK FORCE
COMMITTEE ON SCIENCE & TECHNOLOGY

INDUSTRY'S VIEW OF SCIENCE POLICY RESEARCH FUNDING & MANAGEMENT

RESEARCH FUNDING AND MANAGEMENT

Mr. Chairman, Honorable Members of the House Science Policy Task Force, and Guests:

I am Bill Stickel of Pittsburgh, Pa. and currently hold the position of Director - Patents and Licensing - Corporate Research and Technology Assessment for United States Steel Corporation. Dr. Harry Paxton, our Vice President - Corporate Research and Technology Assessment was scheduled to testify before you today, but had an unavoidable conflict and has asked me to extend his apologies.

I am pleased to appear before the Task Force today to help present "Industry's View of Federal Science Policy" and "The Relationship of Industrial Basic and Applied Research to Government Science Policy". Specifically, I will comment on the issues related to levels of research funding and management of that funding. Recommendations for change will be interjected where appropriate.

RESEARCH FUNDING

Let me first review industry's views on funding levels and trends. You, of course, are familiar with the data but a summary will help set the stage. In December of each year, Battelle Memorial Institute publishes a forecast and analysis of probable levels of R&D expenditures for the coming year. This report makes use of information found in NSF's yearly "National Patterns of Science and Technology Resources", and McGraw-Hill's "Annual Survey of Business Plans for R&D", plus other sources. Battelle's December

1984 report focuses on only 1985 and allows us to separate Federal from industrial funding of R&D.

Battelle's forecast predicts a total R&D expenditure in the United States of $107.3 billion during the calendar year of 1985. This is an increase of 10.6 percent over the estimates of what the final accounting will establish was spent in 1984.

Federal funding in 1985 is expected to be about $48.7 billion (or 45.4 percent of total R&D funding) and represents an increase of $4.4 billion (or 10 percent) from 1984.

1985 will see industry funding 51.3 percent of the total for R&D, or about $55 billion. This is indicative of an 11.4 percent increase or $5.63 billion.

The costs of performing R&D are predicted to rise by 6.5 percent which will obviously significantly reduce the expected increased funding. However, this does leave an expected "real" increase of about 3.8 percent and a new high in total real funding of R&D. The NSF predicts a real growth of over 7 percent.

Estimated sources of funding for R&D by broad industrial class are found in the Battelle report, and can be briefly summarized by stating that other than aerospace, electrical machinery/communications and rubber products, most industry R&D will be paid for primarily by industry funds. The Federal government will fund 32.2 percent while 67.8 percent will be funded by the industries themselves. Increased Federal emphasis on defense and space programs will influence total Federal R&D support with the greatest benefit being experienced by the previously mentioned aerospace, electronics and

COMMUNICATIONS INDUSTRIES. THE BATTELLE REPORT FORECASTS CONTINUING DECREASES IN FEDERAL SUPPORT FOR ENERGY-RELATED R&D PROGRAMS.

COMPARISON OF FEDERAL WITH INDUSTRIAL SUPPORT FOR R&D FROM 1953 ONWARD INDICATES THAT THE FEDERAL GOVERNMENT WAS THE PRIMARY SOURCE OF R&D MONEY FROM 1953 TO 1979, BUT HAS SINCE EXPERIENCED A GRADUAL DECREASE WHEN COMPARED TO THE CORRESPONDING INCREASE OF INDUSTRY FUNDING. INDUSTRY IS NOW THE MAJOR SOURCE OF R&D FUNDS AND ALSO THE PRIMARY PERFORMER OF R&D.

SOME OF THE INCREASE IN INDUSTRY FUNDING MAY BE THE RESULT OF EFFECTS OF THE TAX CREDITS FOR R&D INSTITUTED IN 1981 BUT IT IS TOO EARLY TO SAY. HOWEVER, IT SHOULD BE NOTED THAT THE POSSIBILITY THAT THE TAX CREDIT FOR INCREMENTAL R&D WILL EXPIRE COULD CAUSE A DECREASE IN INDUSTRIAL R&D SPENDING. WHILE IT IS DIFFICULT TO DETERMINE IF THIS SECTION OF THE TAX REFORM ACT OF 1984 HAS BIASED RESEARCH PLANS, IT IS SIMPLE TO OBSERVE THAT THIS CREDIT AGAINST FEDERAL TAX FOR RESEARCH EXPENDITURES IS USEFUL ONLY TO COMPANIES MAKING A PROFIT, AND IS OF LITTLE OR NO VALUE TO MATURE, NEW, OR SMALL COMPANIES WHO BARELY BREAK EVEN OR LOSE MONEY - UNFORTUNATELY A COMMON POSITION.

THOSE OF US IN R&D WOULD LIKE TO THINK THAT EVEN IN AN UNFAVORABLE ECONOMY, RESEARCH WILL BE REGARDED AS A LONG TERM POSITIVE INVESTMENT, AND THE CURRENT ECONOMY IS FAR FROM UNFAVORABLE FOR MANY INDUSTRIES. UNFORTUNATELY FOR MANY OF THE "SMOKESTACK INDUSTRIES", HELP BEYOND THE TAX REFORM ACT IS NEEDED. I UNDERSTAND THAT A RECENT BILL BEFORE THIS COMMITTEE WAS AMENDED TO PROVIDE $6 MILLION IN FEDERAL FUNDS TO HELP

DEVELOP NEW TECHNOLOGY IN THE STEEL INDUSTRY IF IT IS APPROVED. BUT MUCH MORE HELP OTHER THAN DIRECT FINANCIAL SUPPORT, IS NEEDED FOR AUTO, STEEL, RUBBER, TEXTILES AND OTHERS. THE GOVERNMENT MUST CONTINUE TO WORK FOR REALISTIC EXCHANGE RATES FOR THE DOLLAR AND TO ELIMINATE BARRIERS TO U. S. PRODUCTS IN FOREIGN MARKETS, AND UNFAIRLY TRADED IMPORTS.

THE NECESSITY IN ANY INDUSTRY AND IN ANY ECONOMY IS TO HAVE R&D EARN ITS OWN WAY AND THE GOVERNMENT CAN BECOME A PARTNER TO INDUSTRY IN SEVERAL WAYS IN THIS ENDEAVOR.

FEDERAL FUNDING FOR R&D AVAILABLE THROUGH THE AWARDING OF CONTRACTS, THROUGH VARIOUS AGENCIES, RESULTS IN MUCH IMPORTANT RESEARCH BEING PERFORMED THAT MIGHT NOT OTHERWISE BE AFFORDABLE TO INDUSTRY BY ITSELF. HISTORICALLY THE RESULTS OF GOVERNMENT SPONSORED RESEARCH WERE OWNED BY THE GOVERNMENT AND WERE AVAILABLE IN PRINCIPLE TO INTERESTED PARTIES. THEORETICALLY THIS WAS INTENDED TO RESULT IN THE MOST RAPID DISSEMINATION OF NEW DEVELOPMENTS. BUT IN REALITY, THE SPREAD OF NEW TECHNOLOGY IS OFTEN BETTER SERVED BY ALLOWING THE GOVERNMENT-FUNDED PROPRIETARY TECHNOLOGY TO REVERT TO THE COMPANY THAT DEVELOPED IT AND WHICH THEREFORE HAS THE TECHNICAL EXPERTISE TO BEST TRANSFER THE TECHNOLOGY. MORE RECENTLY THE GOVERNMENT HAS MADE CONSIDERABLE PROGRESS IN ALLOWING PATENT RIGHTS TO ACCEDE TO THE DEVELOPER; SOMETIMES THE COMPANY IS REQUIRED TO PAY BACK GOVERNMENT DEVELOPMENTAL MONEY WITH PROFITS EARNED FROM THE SALE OF THE TECHNOLOGY. THE GOVERNMENT COULD, OF COURSE, MAINTAIN PATENT OWNERSHIP AND THE TECHNICAL EXPERTISE OF THE DEVELOPING COMPANY COULD STILL BE SOLD FOR PROFIT. HOWEVER, SINCE THE ABILITY TO LICENSE FOR PROFIT IS OFTEN TIED TO PATENT RIGHTS, AND IN THE LONG TERM THE profit incentive is what drives this economy, the development of advanced technology and, therefore, growth.

Of course, a prime governmental concern is to control anti-competitiveness which may inhibit technological growth. The long standing manifestation of this concern was the Sherman Anti-Trust Act. However, the National Cooperative Research Act of 1984 may result in the more frequent and less fearful formation of joint ventures, and has already had beneficial effects.

FUNDING MANAGEMENT

Industry funding of Research must be directed toward an eventual profit. Levels of funding, of course, are guided by industry's view of the ability to increase profits through the future use and/or sale of the developed technology and, simultaneously, of governmental regulatory constraints that limit savings, sales, or market share

The internal company policies which govern the selection of R&D projects and levels of internal funding vary dramatically across industry, as can be seen by even a brief perusal of the percent of sales invested by different groups. These variations are due to a number of reasons including differences in the life cycle of products, capital requirements for implementation, and market demands.

Generally, recommendations of R&D management are developed in an iterative fashion. Input is sought and received from all areas of a company expected to provide funding, manpower, expertise, facility space, or equipment, and of course to eventually sell the end product. The expense of performing R&D plus often a long turn-around-time to payoff requires all funding commitments to be made typically at a high level, usually by the CEO and/or the Board of Directors.

Cost/benefit analyses are part of every project and many different factors are examined. Government legislation regulations, taxes, tariffs and the general economic climate are always examined carefully. In some cases this may include state and local legislation. In a recent issue of "Research Management" (May-June, 1984) (Volume XXVIII, No.3) Joseph M. Carlson states that, at least for high tech, initiatives and regulatory matters will be most often on the state rather than the federal level. He also predicts that soon larger companies could be dealing with the equivalent of 50 EPAs, 50 OSHAs, or 50 Consumer Product Safety Commissions. This will mean that long range R&D decisions will have further complications as they try to incorporate the need to satisfy these pluralistic government entitities. R&D funding decisions have always been influenced by input from corporate planning departments and commercial research branches supplying information on competition and the market. Where government is the customer for the products of new technology, it can directly

INFLUENCE INDUSTIRAL R&D DECISIONS, BUT OTHERWISE PROJECT CHOICE MUST BE MARKET DRIVEN, AND, OF COURSE, RESPONSIVE TO WHAT THE BUDGET WILL BEAR.

R&D IS MORE OFTEN A COST CENTER THAN A PROFIT CENTER. SOME COMPANIES PERFORM A GREAT AMOUNT OF GOVERNMENT-SUPPORTED RESEARCH - PERHAPS 3/4 OR MORE OF THEIR TOTAL RESEARCH BUDGET - WHILE OTHERS ESPECIALLY IN CONSUMER PRODUCTS DO LITTLE OR NONE. IN SOME COMPANIES A CERTAIN AMOUNT OF CONTRACT RESEARCH ALLOWS THE RETENTION OF A BROADER SPECTRUM OF TALENT WITHIN THE COMPANY, WHOSE SPECIALTIES CAN CONTRIBUTE TO BOTH THE COMMERCIAL AND CONTRACT RESPONSIBILITIES OF AN R&D DEPARTMENT, A NOT INSIGNIFICANT BONUS IN MANY CASES, AND IN MY VIEW ONE WHICH SHOULD BE ENCOURAGED.

LIMITED FUNDS CAN TEND TO LIMIT R&D TO TROUBLE SHOOTING AND QUALITY AND PROCESS IMPROVEMENTS RATHER THAN THE MORE EXPENSIVE AND MORE LONG TERM PROCESS AND PRODUCT DEVELOPMENTS, AND THE VERY NECESSARY UNDERLYING BASIC RESEARCH. ACADEMIC INSTITUTIONS AND SOME NATIONAL LABORATORIES HAVE ALWAYS PERFORMED BASIC, FUNDAMENTAL R&D THAT IS FREQUENTLY BROUGHT TO FRUITION QUITE SLOWLY. INCREASED GOVERNMENT FUNDING OF THESE INSTITUTIONS COULD SUPPORT MORE FUNDAMENTAL RESEARCH FROM WHICH IN PRINCIPLE THE ENTIRE INDUSTRIAL COMMUNITY CAN PROFIT, BUT INCREASED FUNDING PER SE IS NOT NECESSARILY THE MOST APPROPRIATE ROUTE. IN LINE WITH THE OFTEN NECESSARY REQUIREMENT IN INDUSTRY TO "DO MORE WITH LESS", WE BELIEVE THAT AN EXAMINATION OF THE EFFECTIVENESS OF CURRENT PROGRAMS, AND MORE PARTICULARLY, THE WAY IN WHICH DEVELOPMENTS ARE TRANSFERRED TO POTENTIAL USERS, CAN LEAD TO SIGNIFICANT IMPROVEMENTS WITH LITTLE OR NO INCREASE

IN EXPENDITURES.

THE FEDERAL SCIENCE AND TECHNOLOGY COMMITTEE (FST) OF THE INDUSTRIAL RESEARCH INSTITUTE HAS BEGUN A STUDY OF WAYS IN WHICH RESEARCH SUPPORTED BY THE FEDERAL GOVERNMENT CAN, WITH SUITABLE INPUT AT THE PLANNING STAGES, PRODUCE IMPORTANT BENEFITS TO LARGE AREAS OF THE COMMERCIAL (I.E., NON-DEFENSE) ECONOMY. IT HAS BEEN WELL ESTABLISHED THAT THE FALLOUT FROM DEFENSE-SPONSORED RESEARCH HAS ENABLED THE U.S. TO MAINTAIN INTERNATIONAL COMPETITIVENESS IN FIELDS SUCH AS AEROSPACE, TELECOMMUNICATIONS AND COMPUTER SCIENCE. TWO RECENT REPORTS - THE PRESIDENTIAL COMMISSION ON INTERNATIONAL COMPETITIVENESS AND THE PACKARD REPORT ON FEDERAL LABORATORIES HAVE URGED THAT WE LOOK FOR WAYS TO PRODUCE SIMILAR EFFECTS IN OTHER INDUSTRIES WHICH, FOR WHATEVER REASONS, HAVE BEEN HAVING DIFFICULTY IN MAINTAINING LEADERSHIP POSITIONS IN THE INTERNATIONAL TRADE ARENA.

SOME YEARS AGO, THE FST/IRI COMMITTEE BEGAN A PROGRAM WITH FEDERAL LABORATORIES TO ACQUAINT THEM WITH SOME AREAS OF INDUSTRIAL RESEARCH INTEREST, AND IN TURN TO BECOME MORE FAMILIAR WITH PROGRAMS IN THE LABORATORIES. FROM MODEST BEGINNINGS, THE EFFORT HAS GROWN IN A SATISFYING FASHION. ALTHOUGH MUCH MORE REMAINS TO BE DONE, THE ENTHUSIASM, INTEREST AND COMPETENCE DISPLAYED BY THE LAB DIRECTORS AND THEIR STAFFS HAS BEEN MOST ENCOURAGING TO US IN INDUSTRY. THE EXISTENCE OF THESE TIES CERTAINLY FACILITATED THE PLANNING FOR THE KEYWORTH INITIATIVE IN THE STEEL INDUSTRY, FOR EXAMPLE.

INDUSTRY IS ALSO INTERESTED IN THE RESEARCH PERFORMED IN ACADEMIC INSTITUTIONS WHICH ARE CONSIDERED FOR PROJECT FUNDING WHEN INDUSTRIAL R&D MONEY IS ALLOCATED. CURRENTLY ABOUT 7% OF UNIVERSITY RESEARCH IS SUPPORTED BY INDUSTRY. UNIVERSITIES CARRY OUT A SIGNIFICANT AMOUNT OF THE TOTAL BASIC RESEARCH IN THE U.S.A., AND THIS IS MOST PROPER. IMAGINATIVE AND FERTILE MINDS MUST BE ALLOWED THE FREEDOM TO DEVELOP THEIR OWN IDEAS, AND SIGNIFICANT INTERFERENCES WITH THIS FUNCTION WILL IN THE LONG RUN BE COUNTER PRODUCTIVE TO OUR NATION. HOWEVER, IN SELECTED CASES, BOTH ACADEMIC AND INDUSTRIAL RESEARCHERS CAN BENEFIT FROM WORKING TOGETHER ON JOINT PROGRAMS. THERE ARE SOME CAVEATS.

FIRST, A COMPLETE UNDERSTANDING OF THE GOALS AND OBJECTIVES OF A JOINT INDUSTRY-UNIVERSITY EFFORT IS PARAMOUNT. TWO DIVERSE MOTIVATIONS FOR DOING RESEARCH, KNOWLEDGE-DRIVEN FROM THE UNIVERSITY AND PROBLEM SOLVING ORIENTED FROM THE INDUSTRIAL ENTERPRISE CAN LEAD TO DIFFICULT PROBLEMS AND MUST BE RECONCILED AT THE OUTSET.

SECOND, THE QUESTION OF OWNERSHIP OF INTELLECTUAL PROPERTY RESULTING FROM THE JOINT EFFORT MUST BE RESOLVED. THE COMMERCIAL PROTECTION AND EXPLOITATION IS CRITICAL TO THE PROFIT ORIENTATION OF INDUSTRY. THE NEED TO PUBLISH IS CRITICAL TO THE UNIVERSITY AND THE TWO OFTEN CLASH.

NEITHER OF THESE PROBLEMS ARE INSURMOUNTABLE, BUT MUST BE RECOGNIZED.

Tax laws could perhaps be modified to encourage greater industry funding of university projects. Current tax policy does encourage industry to donate equipment to research universities. An additional benefit from University-Industry interaction is the exposure provided to students of the trends, positions, projects and priorities of industry allowing the graduates to seek informed careers.

It is my belief that both industry and government will jointly have to find ways to utilize R&D effectively in the coming years to keep the United States in the forefront of the technological age. And I also believe that even in these times of massive federal deficits and excessive red ink in industry, the dollar spent on R&D is a dollar invested in the future economic stability.

Most industries will have to change to more strongly link R&D departments to other corporate decision making areas so research is better planned and managed. More market, academic and political awareness will be needed to compete effectively along with a willingness to look into new ways of doing business such as joint venture cooperative research and perhaps contracting out certain research activities.

Government's role should perhaps change also, to allow a greater emphasis on providing the atmosphere and environment most likely to encourage R&D investment, rather than to set up a "national policy" which could result in attempts to manage and control commercial R&D choices. This implies a favorable tax climate with special R&D tax credits, new intellectual property legislation, continuing less stringent interpretations

OF ANTI-TRUST LAW, NEW DEPRECIATION ALLOWANCES, A CLIMATE FOR A MORE PROFITABLE INTERACTION BETWEEN NATIONAL LABS AND UNIVERSITIES AND INDUSTRY, AND EFFORTS TO KEEP FAIR ACCESS TO DOMESTIC AND FOREIGN MARKETS. ALONG THESE LINES, A PROPOSED PROJECT BY THE INDUSTRIAL RESEARCH INSTITUTE'S FEDERAL SCIENCE AND TECHNOLOGY COMMITTEE WILL STUDY THE NEED FOR APPROPRIATE LINKING MECHANISMS BETWEEN INDUSTRIAL RESEARCH, THE FEDERAL GOVERNMENT AND FEDERAL RESEARCH ESTABLISHMENTS. PERHAPS SOME OF THE NECESSARY INTERACTIONS WILL BE DEVELOPED THERE.

R&D IS ALL TOO OFTEN EQUATED TO INNOVATION AND THOUGH THAT IS A SIGNIFICANT PART, IT IS ALSO BUILDING ON THE WORK OF OTHERS. IT IS DEEPLY INGRAINED IN THE AMERICAN MIND THAT WE LEAD AND OTHERS FOLLOW, BUT AS PROVEN BY THE JAPANESE AND NOW THE KOREANS, TAKING A COMPETITORS INNOVATION AND DOING IT BETTER, CHEAPER AND MORE QUICKLY CAN PAY OFF DRAMATICALLY.

INFORMED RESEARCH MORE AND MORE WILL REQUIRE KNOWLEDGE OF WORLDWIDE DEVELOPMENTS, MARKETS AND LAWS. TO THE EXTENT THAT GOVERNMENT CAN ACT EFFECTIVELY AS A SOURCE OF CURRENT AWARENESS, E.G., STATE DEPARTMENT SCIENCE ATTACHÉS, SHOULD ACT AS A FEDERAL CLEARING HOUSE FOR INFORMATION TO STIMULATE INDUSTRY. IT CAN ALSO BE A MOST IMPORTANT PARTNER IN ENACTING THE LEGISLATION TO PERMIT U. S. INDUSTRY TO FUNCTION BEYOND INNOVATION WITH A MINIMUM OF UNNECESSARY INTERFERENCES.

TO SUMMARIZE, MANY FEATURES OF GOVERNMENT-INDUSTRY INTERACTION ARE MUCH BETTER THAN THEY WERE ONLY A FEW YEARS AGO, BUT CONTINUAL INTENSIFICATION OF INTERNATIONAL COMPETITION MUST NOT LEAVE EITHER GROUP IN ANY WAY SELF-SATISFIED. WE COMMEND THIS COMMITTEE FOR RECOGNIZING THE IMPORTANCE OF SCIENCE AND TECHNOLOGY, AND BY CAUSING US TO REVIEW THE EXISTING SITUATION, TO MAKE US BOTH CONTINUE OUR SEARCH FOR EFFECTIVE WAYS OF USING OUR VERY CONSIDERABLE RESEARCH EXPENDITURES TO MAINTAIN OUR NATION'S VIABILITY.

THANK YOU FOR LISTENING, AND IF THERE ARE QUESTIONS, I WOULD BE PLEASED TO TRY TO PROVIDE FURTHER INFORMATION.

STATEMENT OF DR. SAMUEL TINSLEY, DIRECTOR OF TECHNOLOGY PLANNING, UNION CARBIDE CORP., DANBURY, CT; ON BEHALF OF THE INDUSTRIAL RESEARCH INSTITUTE

Dr. TINSLEY. There is something I should have said at the beginning. Although we appear under the auspices of the Industrial Research Institute, it, like the House, is a pretty large, pluralistic organization, and we do not arrive at positions with a lot of speed. Therefore, what you are hearing, I think, rather than positions of the Institute, except where stated, is more a reflection of the experiences of the individual involved.

My first topic is incentives for basic research. Now, that is an issue that sounds pretty noncontroversial, sort of like incentives for motherhood and apple pie.

I assume it stems from the widely held, but not rigorously proven, belief that there is a demonstrable connection between basic research and applied research and development; that applied research and development is an integral factor in technical innovation; that technological innovation accounts for a significant part of our productivity gains, our international competitiveness—and, therefore, our economic health—and, finally, that since the social return on R&D is generally a multiple of the return to the investing company, the private sector will never invest the optimum amount, from society's standpoint, of resources in R&D.

Therefore, the Government should encourage private sector R&D and should fund a significant amount of basic research in addition to its mission-related R&D investment.

In general agreement with these beliefs, and in deep appreciation of the role universities play in performing basic research, the IRI has affirmed the importance of continued direct Federal funding of basic research conducted primarily in universities and recommended back in 1980 that the Federal Government provide Federal tax incentives to stimulate industrial support of university research and graduate education, and encourage Federal funding agencies to manage their programs in ways that enhance couplings of universities and industry.

The IRI has applauded the 1981 tax credit and hopes that it will be extended. My personal opinion is that that extension is crucial, since I believe we have sort of a piece of an experiment here—a piece, since a 3-year tax credit represents a timeframe that is one-third to one-half the timeframe of our major new projects. Furthermore, the uncertainty regarding termination or extension is difficult to accommodate in normal business planning practice.

As for specific incentives for basic research, until recently I would have said I have no recommendation. I thought that basic research support, much like the degree of enlightened self-interest of corporate management, was directly related to the health of a firm's balance sheet and to the strategic vision of the firm; further, that the consistent increase in industrial R&D over the last several years was due to management's appreciation of the idea that while asset management may be appropriate for short-term financial problems, technology management is the critical factor in long-term growth.

However, in a recent questionnaire on trends in R&D, 157—which is well over 50 percent—of our member firms responded. Of those responding, 42 percent expected to do about the same amount of directed basic research in 1985 as in 1984. However, 36 percent expected to do slightly more, and 5 percent, significantly more.

Now, the last time we did a trend survey was about 10 years ago, and at that time, those last two numbers were 22 percent expected to do slightly more and only 1 percent significantly more. So maybe we should look a little harder at the effects of that tax credit and see if it is having a positive effect on basic research.

My other topic was manpower projections. I think I can skip that because you covered that in the previous session. Your comments exactly agreed with our experience. We are having no trouble finding and hiring the people we want to hire. Admittedly, we hire primarily chemists and chemical engineers, not some of the more esoteric disciplines, and the quality is excellent.

Mr. Smith brought out a point that we do have some concern about, and that is the decreasing percentage of U.S. citizens taking the Ph.D. degree in the hard sciences and engineering. It not only makes you wonder about who is going to be doing our teaching and research in the future if our research expenditures go up as most of us project; but also, have we turned off a whole generation? Is it really a problem of education of our students and possibly our citizenry?

Thank you.

[The prepared statement of Dr. Tinsley follows:]

THANK YOU FOR THIS OPPORTUNITY TO BE HERE TODAY AND TO CONTRIBUTE, HOPEFULLY, TO YOUR REVIEW OF AMERICAN SCIENCE POLICY. THERE IS A RICH LITERATURE ON THE SUBJECT; HOWEVER, IN VIEW OF THE RECENT STRUCTURAL CHANGES IN MANY SECTORS OF OUR MANUFACTURING INDUSTRY, IT SEEMS AN APPROPRIATE TIME FOR A COMPREHENSIVE REVIEW AND FOR POSSIBLE SELECTION OF NEW DIRECTIONS.

I AM SAM TINSLEY, CURRENTLY PRESIDENT OF THE INDUSTRIAL RESEARCH INSTITUTE AND THE REPRESENTATIVE OF THE UNION CARBIDE CORPORATION. THE IRI IS AN ORGANIZATION COMPRISING THE R&D CHIEFS ON SOME 280 COMPANIES. THESE COMPANIES PERFORM ABOUT 85% OF THE R&D DONE IN THE UNITED STATES.

MY PERSONAL EXPERIENCE INVOLVES 17 YEARS IN CHEMICAL R&D, 5 YEARS IN NEW CHEMICAL DEVELOPMENT MANAGEMENT, 6 YEARS OF TECHNOLOGY MANAGEMENT IN NEW BUSINESS DEVELOPMENT, AND 5 YEARS AS DIRECTOR OF CORPORATE TECHNOLOGY - ALL WITH UNION CARBIDE.

THE ISSUE OF INCENTIVES FOR BASIC RESEARCH SOUNDS FAIRLY NON-CONTROVERSIAL -- SOMETHING LIKE INCENTIVES FOR MOTHERHOOD AND APPLE PIE. I ASSUME IT STEMS FROM THE WIDELY-HELD, BUT NOT RIGOROUSLY PROVEN, BELIEFS:

> THAT THERE IS DEMONSTRABLE CONNECTION BETWEEN BASIC RESEARCH AND APPLIED RESEARCH AND DEVELOPMENT.
>
> THAT APPLIED RESEARCH AND DEVELOPMENT IS AN INTEGRAL FACTOR IN TECHNOLOGICAL INNOVATION.

THAT TECHNOLOGICAL INNOVATION ACCOUNTS FOR A SIGNIFICANT PART OF OUR PRODUCTIVITY GAINS, OUT INTERNATIONAL COMPETITIVENESS, AND, THEREFORE, OUR ECONOMIC HEALTH.

FINALLY THAT, SINCE THE SOCIAL RETURN ON R&D IS GENERALLY A MULTIPLE OF THE RETURN TO THE INVESTING COMPANY, THE PRIVATE SECTOR WILL NEVER INVEST THE OPTIMUM AMOUNT, FROM SOCIETY'S STANDPOINT, OF RESOURCES IN R&D.

THEREFORE, THE GOVERNMENT SHOULD ENCOURAGE PRIVATE SECTOR R&D AND SHOULD FUND A SIGNIFICANT AMOUNT OF BASIC RESEARCH IN ADDITION TO ITS MISSION-RELATED R&D INVESTMENT.

IN GENERAL AGREEMENT WITH THESE BELIEFS AND IN DEEP APPRECIATION OF THE ROLE UNIVERSITIES PLAY IN PERFORMING BASIC RESEARCH, THE IRI HAS AFFIRMED THE IMPORTANCE OF CONTINUED DIRECT FEDERAL FUNDING OF BASIC RESEARCH CONDUCTED PRIMARILY IN UNIVERSITIES AND RECOMMENDED, IN 1980, THAT THE FEDERAL GOVERNMENT:

PROVIDE FEDERAL TAX INCENTIVES TO STIMULATE INDUSTRIAL SUPPORT OF UNIVERSITY RESEARCH AND GRADUATE EDUCATION.

ENCOURAGE FEDERAL FUNDING AGENCIES TO MANAGE THEIR PROGRAMS IN WAYS THAT ENHANCE COUPLING OF UNIVERSITIES AND INDUSTRY.

THE IRI HAS APPLAUDED THE 1981 R&D TAX CREDIT AND HOPES THAT IT WILL BE EXTENDED. MY PERSONAL OPINION IS THAT EXTENSION IS CRUCIAL SINCE I BELIEVE WE HAVE SORT OF A PIECE OF AN EXPERIMENT - A PIECE SINCE A THREE-YEAR TAX CREDIT REPRESENTS A TIME FRAME THAT IS ONE-THIRD TO ONE-HALF THE TIME FRAME OF OUR MAJOR NEW PROJECTS. FURTHER, THE UNCERTAINTY REGARDING TERMINATION OR EXTENSION IS DIFFICULT TO ACCOMMODATE IN NORMAL BUSINESS PLANNING PRACTICE.

AS FOR SPECIFIC INCENTIVES FOR BASIC RESEARCH, UNTIL RECENTLY I WOULD HAVE SAID I DID NOT HAVE A RECOMMENDATION. I THOUGHT THAT BASIC RESEARCH SUPPORT, LIKE THE DEGREE OF ENLIGHTENED SELF-INTEREST OF CORPORATE MANAGEMENT, WAS DIRECTLY RELATED TO THE HEALTH OF THE FIRM'S BALANCE SHEET AND THE STRATEGIC VISION OF THE FIRM. FURTHER, THAT THE CONSISTENT INCREASE IN INDUSTRIAL R&D OVER THE LAST SEVERAL YEARS WAS DUE TO MANAGEMENT'S APPRECIATION OF THE IDEA THAT, WHILE ASSET MANAGEMENT MAY BE APPROPRIATE FOR SHORT-TERM FINANCIAL PROBLEMS, TECHNOLOGY MANAGEMENT IS THE CRITICAL FACTOR IN LONG-TERM GROWTH.

HOWEVER, IN A RECENT QUESTIONAIRE ON TRENDS IN R&D, 157 OF OUR MEMBER FIRMS RESPONDED. OF THOSE RESPONDING, 42% EXPECTED TO DO ABOUT THE SAME AMOUNT OF DIRECTED BASIC RESEARCH IN 1985 AS IN 1984; HOWEVER, 36% EXPECTED TO DO SLIGHTLY MORE AND 5% SIGNIFICANTLY MORE. MAYBE WE SHOULD LOOK A LITTLE HARDER AT THE EFFECT OF THAT TAX CREDIT TO SEE IF IT IS HAVING A POSITIVE EFFECT ON BASIC RESEARCH.

Mr. **Fuqua**. Dr. McHenry.

[A biographical sketch of Dr. McHenry follows:]

Dr. Keith W. McHenry, Jr.

Keith W. McHenry, Jr. is vice president, research and development, for Amoco Oil Company, a Standard Oil Company (Indiana) subsidiary. He is in charge of all R&D on process and products for domestic and international refining and marketing and of most work on processing future petroleum substitutes.

McHenry received a B.S. in chemical engineering from the University of Illinois and a Ph.D. in chemical engineering from Princeton University. His entire industrial career has been with Standard Oil Company (Indiana) and its subsidiaries. He is a member of the National Academy of Engineering, Chairman of the Industrial Advisory Board of the Engineering College of the University of Illinois at Chicago, a trustee of North Central College, and a member of the Board of Directors of the Industrial Research Institute (IRI). Previously, he chaired the University Relations Committee of IRI and has served on advisory committees at the University of Delaware and Princeton University.

STATEMENT OF DR. KEITH W. McHENRY, JR., VICE PRESIDENT, RESEARCH AND DEVELOPMENT, AMOCO OIL CO., NAPERVILLE, IL; ON BEHALF OF THE INDUSTRIAL RESEARCH INSTITUTE

Dr. **McHenry**. Mr. Chairman, my part of the Industrial Research Institute panel is to discuss the nature of industry-university relations and the adequacy of the training of engineers and scientists who are employed in industrial research. I plan to comment rather extensively on the former but will make only limited comments on the manpower question.

You have written copies of my testimony which should be made part of the record. I do not plan to read it all. In order to leave some time for questions, I will only summarize.

To gain some insight into how the university-industry research relationship works, let's look first at the roles played by R&D in the industrial organization. Among those roles are finding new markets, helping operating departments, technology planning and forecasting, and being the technical conscience of the firm.

There are some roles for R&D that have been thought of as traditional but are purposely left out of the preceding. University or Government researchers might want to list develop technology or advance science as purposes. The point is that R&D, in an industrial organization, is there to serve some business purpose, and that role may be one of the most important reasons why communication between industrial research managers and university administrators gets sticky.

Our researchers and theirs will want to talk about technology as is very appropriate. My counterparts in industrial R&D and university administrators will have to talk about business purposes in order to establish lasting relationships.

Because of those underlying business purposes, there are large differences among industrial labs. While there are some rather standard organizations, no two companies are exactly alike. For outside organizations to communicate well, they need to understand just what kinds of tasks are being performed and for what specific purposes.

Government programs targeted to encourage one kind of industry-university research effort—say, new product development—will not be helpful to industrial laboratories aimed, for example, at developing processes.

A major similarity among industrial research labs is that they are interdisciplinary. When a problem is to be solved, teams made up of people with the necessary skills, not necessarily the same academic backgrounds, are formed routinely.

Single-discipline outside research projects are frequently supported by industry, but the outside lab that brings an interdisciplinary approach has a better chance of gaining industrial cooperation, all other factors being equal. This is why industry reaction to the interdisciplinary NSF Engineering Research Center program has been generally favorable.

Next let us look at mechanisms for industry support at universities. Some of these are philanthropic donations with essentially no strings attached. These are likely to be given to whole universities to cover broad areas and, in many cases, to be granted through corporate foundations.

Second are fellowships and direct student support programs. Many times these programs are also centrally controlled and often depend on relative recruiting success at various schools and departments.

Third is professor support. I can think of two types, general and specific. The motivation for the general type is, for example, we need to support young faculty in chemical engineering because there is a shortage of qualified professors. For the specific type, it is more likely to be Professor X has a good research program; let's give him some unrestricted support.

Fourth is departmental support, also of general and specific types. General: chemical engineering departments are short of funds for equipment to teach undergraduates; contrasted with specific: department Y is really moving up; let's give the chairman some money to start some new programs.

Fifth is general affiliate programs, those where whole universities, like Caltech and MIT, or individual departments, like chemistry at Stanford and Northwestern, solicit a fixed fee from a group of companies.

Sixth is direct research support. Most common are one-on-one deals with a professor or a group of professors that deliver some kind of wanted research to a company or a to a consortium. The ultimate is company-university arrangements such as that between Monsanto and Harvard.

The motivations for industry support of the university are generally obvious. Public image is important in some instances. Maintaining the supply of trained manpower out into the future is perhaps the prime mover for industry support by companies. However, access to consultants and the best science probably runs a close second.

There is a need for rapid transfer of basic research results, which implies that many, if not most, industrial labs depend on universities for basic research.

The written testimony has several examples of university-industry cooperation. I will merely summarize what might be learned from them.

The first example was an industry consortium supporting a basic research effort in a specialized field. From that we learned that successful cooperation is likely if the university has success to sell. This suggests the use of seed money if possible. In this specific example, NSF funds and university funds were used to start the research program before industry was called in.

Second, if an industrial advisory board is set up, it should give advice and not just be a body to report to.

Third, initial commitments should be made as simple as possible. Agreements made ahead of time to cover all eventualities are not likely to be workable.

The second example I chose is the NSF Cooperative University-Industry Research program. From an industry point of view, this is a very strong program because it leverages private funds with NSF funds. However, my personal observation is that some of the universities are not very interested in the program. Clearly, other company and/or university views of the program may differ from ours.

A relatively new program which appears to be very popular with universities is the Presidential Young Investigator awards. Recipients can get up to $100,000 per year of mixed Government and industry support for 5 years. Many companies have responded with grants.

However, the PYI grants have not been viewed quite so positively by some companies. Requests for matching funds came to the same companies who were already funding a lot of cooperative research or philanthropic giving. A complete commitment is sizable, nearly $200,000 over 5 years. Except for the largest companies, these funds would most likely come from other programs to some extent. Therefore, some requests have been turned down.

A suggested mode of operation which seems to be catching on is to try to get companies involved who have not been involved in giving to university research before, perhaps as consortia of smaller companies. I am personally disappointed that the number of PYI grants will be cut from 200 to 100 in the next round.

Two other examples in the testimony deal with research that is done for the benefit of a whole industry. It seems likely that future industry-wide cooperative research programs will succeed in industries which have similar characteristics.

These are growth, some established technology, and considerable empiricism. Growth implies considerable funding, not strong competition for diminishing markets. Some established technology is necessary so that the industry can agree on what it needs. Empiricism implies that there is room for some basic research work in the area that universities can cover best.

Science policymakers need to consider industry characteristics in determining what kinds of cooperative efforts to support or encourage.

The written testimony includes a discussion of the potential problems and conflicts in the university research cooperation. In the interest of saving time, I will not repeat them here. Suffice it to say that I have yet to see a problem that could not be solved if the parties involved really wanted something to happen.

The future of industry-university research relations seems likely to be evolutionary. High-technology companies in areas like biotechnology, electronics, robotics and so forth will continue to want access to research in the universities.

However, I believe we will see a new trend in smaller companies wanting access to technology as opposed to research. This is information that the faculty already has and that the companies can apply. This suggests opportunities for the universities in the area of short courses, team consulting, and perhaps on-campus training of key company people.

Another trend is that the industrial R&D giants are changing their organizational styles. They are moving toward fewer layers of supervision and more decisionmaking by engineers and scientists. Thus, there will be more emphasis on careers which depend on technical as opposed to managerial talents. These technologists will demand more access to university research.

And, finally, what about the role of the Federal Government? The foregoing has suggested characteristics of success of some Federal programs in support of the university-industry research cooperation; to summarize, first, providing seed money.

NSF grants which anticipate later industrial support appear to have worked well in the past. The new NSF engineering research center program is in the same vein. However, NSF should be prepared to cease support of centers which are not gaining industrial support.

Second, providing matching funds. Industry welcomes programs where their funds can be leveraged with Federal dollars. University programs where the chances of proprietary advantage are relatively small are easier to fit into tight R&D budgets if matching support to the university is available. Both the NSF cooperative university-industry research program and the PYI program provide such support.

Third, providing other incentives to industry to cooperate with universities. The R&D tax credits given for contract work at universities in the current law and the extension to gifts of equipment from industry to universities are programs which should have positive consequences.

Fourth, providing direct support to universities. While the Federal Government supplies the bulk of support to university research, it needs to continue to be alert to the changing needs of those institutions. Future faculty needs are being addressed in part through the PYI program.

Current and future equipment needs are also critical. Strong faculties with up-to-date equipment will not only attract research support from industry but also supply the well-trained graduates that industry needs.

My testimony has also pointed out the complexity of the industrial research effort and how this causes difficulties with university relationships. The warning for science policymakers is that programs to encourage university-industry research cooperation which are tightly specific and targeted may fail because only a few relationships will fit the program. Thus, I would recommend general programs, flexibility, and a willingness to respond to needs uncovered by the cooperating participants themselves.

I have not highlighted new needs or recommended new programs. My perception is that the Federal Government is aware of the needs of the universities and their industrial partners.

The programs which are in place at NSF appear to be working. However, as the mission agencies support more of the basic research load, we should be sure that NSF or the agencies themselves are alert to possible changing university problems and the need to address them through new programs.

Let me close by briefly mentioning the adequacy of training of scientists and engineers. The specific question posed to the IRI panel was: Is industry obtaining people who have the proper training commensurate with their scientific discipline and level of academic achievement? My answer to the question is generally affirmative.

My company hires 20 to 50 research engineers and scientists each year, mostly in traditional disciplines. We are satisfied that B.S engineers are well trained in the fundamental; that the M.S. graduates have learned specialized techniques of interest to us; and that the Ph.D.'s have learned the basics of carrying out original research.

Two related areas stand out as open for improvement. First, as technical horizons broaden, breadth of training becomes important. For example, B.S. chemical engineers who plan to work in biotechnology need almost all of their current training plus a background in microbiology. If the same engineer plans to work in the computer chip industry, he or she will need some basic information about microelectronics. The questions on breadth are not easy ones, but I believe that the universities are beginning to address them.

The related problem is that of interdisciplinary teamwork. It is too much to ask that individuals have all the breadth necessary to successfully pursue today's research problems; hence industry's emphasis on research teams. Training on interdisciplinary teams appears to be missing in the qualifications of many of today's advanced degree graduates. Here the universities may not be moving as rapidly toward changes as industry would like.

A lurking problem probably beyond the scope of today's hearing is the adequacy of precollege training in science and mathematics. The individuals who make their way into careers in research generally seek out good precollege training or overcome the handicap of poor training. However, such training handicaps will make it difficult for the Nation as a whole to compete in the highly technological world economy.

It is not clear to me what the Federal Government's role, if any, should be in solving the breadth question. However, continuing emphasis, as in the Engineering Research Center program, on interdisciplinary cooperative research will certainly help the university departments move beyond their disciplinary boundaries.

Federal concern about the precollege education problem must continue and grow more focused. On balance, with emphasis on research support which recognizes the university's unique role as educators as well as research performers, I believe we will continue to have access to an adequate supply of appropriately trained scientists and engineers. Thank you.

[The prepared statement of Dr. McHenry follows:]

A third role played by R&D is in technology planning and forecasting. The firm wants to know what the competition is going to do and what technology they are likely to have to do it with. And, finally, R&D is expected to be the technical conscience of the firm. It tries to make sure the marketing or manufacturing people don't get carried away with ideas that are technically impractical.

There are some roles for R&D that have been thought of as traditional but are purposely left out of the preceding discussion. University or government researchers might want to list "develop technology" or "advance science" as purposes. The point is that R&D in an industrial organization is there to serve some business purpose, and that role may be one of the most important reasons why communication between industrial research managers and university and government lab administrators gets sticky. Our researchers and theirs will want to talk about technology -- as is very appropriate. My counterparts in industrial R&D and university/government administrators will have to talk about business purposes in order to establish lasting relationships.

Because of those underlying business purposes, there are large differences among industrial labs. Single laboratories may serve the existing business of the firm with a range of activities. Some

TESTIMONY TO HOUSE SCIENCE POLICY TASK FORCE

APRIL 23, 1985
Keith W. McHenry, Jr.

As a part of the group of Industrial Research Institute Directors testifying today, I have been asked to discuss the nature of industry/university relations and the adequacy of the training of engineers and scientists who are employed in industrial research. I plan to comment rather extensively on the former, but will make only limited comments on the manpower question. My comments on industry/university relations are based in large part on an address given to a workshop entitled "Cooperation for Economic Growth," which was sponsored by the Society of Research Administrators in November, 1984. In it I also considered some of the generic problems in doing joint work with government laboratories, and I will discuss these as well. I hope that my remarks will be useful to your Task Force.

UNIVERSITY/INDUSTRY RESEARCH RELATIONS

Industrial R&D

In order to gain some insight into how the university/industry research relationship works, let's look first at the role played by R&D in the industrial organization. Helping the operations departments in the company is the number one priority of many labs. Finding new markets is another task often given to R&D. The lab gives the firm entry into those markets by developing new products and services.

activities may be thought of as exploratory work, some development, and some technical service -- applying known technology to solve problems. Other single laboratories may be focused on developing new businesses. Still others serve both ends. In large companies especially, all three types can be more-or-less closely affiliated. While there are some rather standard organizations, no two companies are exactly alike.

For outside organizations to communicate well, they need to understand just what kinds of tasks are being performed and for what specific purposes. Government programs targeted to encourage one kind of university/industry research effort, say new product development, will not be helpful to industrial laboratories aimed, for example, at developing processes.

A major similarity among industrial research labs is that they are interdisciplinary. When a problem is to be solved, teams made up of people with the necessary skills, not necessarily the same academic backgrounds, are formed routinely. Single-discipline outside research projects are frequently supported by industry, but the outside lab that brings an interdisciplinary approach has a better chance of gaining industrial cooperation, all other factors being equal. This is why industry reaction to the interdisciplinary NSF Engineering Research Center program has been generally favorable.

Working with Universities and Government Labs

Next, let's look at our view of working with university and government labs, starting with mechanisms for industry support at universities. Some of these are:

(1) Philanthropic donations with essentially no strings attached. These are likely to be given to whole universities, to cover broad areas, and, in many cases, to be granted through corporate foundations.

(2) Fellowships and direct student support programs. Many times these programs are also centrally controlled and often depend on relative recruiting success at various schools and departments.

(3) Professor support. I can think of two types -- general and specific. The motivation for the general type is, for example, "We need to support young faculty in chemical engineering because there is a shortage of qualified professors." For the specific type it is more likely to be, "Professor X has a good research program. Let's give him some unrestricted support." The general type is usually under central control, while the specific type is under control of the R&D department.

(4) Departmental support, also of general and specific types. "Chemical engineering departments are short of funds for equipment to

teach undergraduates," contrasted with, "Department Y is really moving up. Let's give the chairman some money to start some new programs." The same funding source comparison holds as for faculty support. Usually the general type is centrally controlled and the specific type more likely to be controlled by the R&D organization.

(5) General "affiliate" programs, those where whole universities, like Caltech and MIT, or individual departments, like chemistry at Stanford and Northwestern, solicit a fixed fee from a group of companies. Gain for the companies is better contact with faculty, exclusive seminars, etc. Support is likely to come from the industrial R&D department rather than from a centrally controlled foundation because a quid pro quo is involved. However, this differs among companies.

(6) Direct research support. Most common are one-on-one deals with a professor or group of professors to deliver some kind of wanted research to a company or to a consortium.

The motivations for industry support of universities are generally obvious. Public image is important in some instances. Maintaining the supply of trained manpower out into the future is perhaps the prime mover for university support by companies. However, access to consultants and the best science probably runs a close second. There is a need for rapid transfer of basic research results which implies that many, if not most, R&D labs depend on the universities for basic research. The rewards go to those who are swift to develop those results into a plan or design for a new product, process, or service -- which is a broad definition of industrial R&D. If support of the university in some way will make us a little swifter than our competitors, then we'll give that support.

The opportunities for industry support of government laboratories are much more limited because there are no philanthropic motives and no recruiting motives. Basically what we are looking for is access to resources we don't have. These can be people, technology, or equipment. The mechanisms are:

(1) Cooperative research. Examples are multicompany programs with the government lab as the organizer and, perhaps, chief performer of the work. There were many projects like this during the era of synthetic fuels and other complex energy projects.

(2) Contract research, funded by one company, with one government lab doing work that the company cannot do for itself.

(3) Affiliates groups. Some government labs are starting industrial advisory groups, usually without funding by the companies represented, in order to get industrial input into their programs.

Examples of University/Industry Cooperation

The examples which follow were chosen because of personal experience. Obviously there are many others which are working equally well.

First is the Center for Catalytic Science and Technology at the University of Delaware. This particular illustration was chosen because of a good record of continuing success with industrial support.

There are a number of reasons for this success. Initial contact with industry was made some time before the Center asked for industrial support, mainly through a short course in catalysis given by the Center. A clear commitment to interdisciplinary efforts was apparent.

Equally important, the formation of the industrial advisory board for the Center took place after a good start had been made with initial NSF funding. The advisory board didn't want to be responsible for how the Center was managed, but only to give general direction as to the types of research. Industry was quite clear that the Center should stick to basic research and not try to invent and develop commercial products.

Everything should be open, and everyone should have an equal chance to see what was going on. If a company saw something interesting, it would be able to develop the idea in its own laboratory. If the Center were granted a patent, all the companies wanted was for no one of them to have an unfair advantage. Licenses should be available on equal and reasonable terms to all. Most of the advice was heeded by the University.

Conclusions which could be reached from this example include the following:

(1) Successful cooperation is likely if the university has success to sell. This suggests the use of seed money if possible. In addition to NSF, the University of Delaware Foundation helped initially.

(2) If an industrial advisory board is set up, it should give advice and not just be a sink for reports.

(3) Initial commitments should be as simple as possible. Agreements made ahead of time to cover all eventualities are not likely to be workable.

The next example is NSF Cooperative University-Industry Research. From an industry point of view, this is a very strong program. NSF contributes funds to a university, and industry pays to have some of its staff or facilities involved in the joint research. The program offers a chance to leverage cooperative research money with the NSF contribution. It gets industrial people involved with the university so that they know what's going on. However, my personal observation is that the universities are not very interested in this program. Our laboratory gets many proposals for funding university research, but very few have suggested that the NSF cooperative program would be a good way to carry it out. The one or two programs we are involved with came about because we suggested the NSF approach. Clearly, other company and/or university views of the program may differ from ours.

A new program which appears to be very popular with the universities is the Presidential Young Investigator Awards. These are very good for the recipients. They can get up to $100 thousand per year of mixed government and industry support for five years. Many companies have responded with grants.

However, the PYI grants have not been viewed quite so positively by some companies. Requests for matching funds came to the same companies who were already funding a lot of cooperative research or philanthropic giving. A complete commitment is sizable -- nearly $200 thousand over five years. Except for the largest companies, these funds would most likely come from other programs to some extent. Therefore, some requests have been turned down. A suggested mode of operation, which seems to be catching on, is to try to get companies involved who have not been involved in giving to university research before, perhaps as consortia of smaller companies.

Another way to think about university/industry research cooperation is in the context of research that is done for the benefit of a whole industry. I have chosen two examples, past and present, to illustrate such cooperative work.

The American Petroleum Institute (API) Project 44 was carried out at Penn State during and after World War II to measure and correlate physical properties of petroleum fractions. It developed basic knowledge useful to the entire petroleum industry. The characteristics of the industry at the time were growth, some established technology, and considerable empiricism.

The Semiconductor Research Cooperative was established two years ago at Research Triangle Park in North Carolina. It consists of 25 companies and 11 universities banded together to address the industry's fundamental research needs in an organized way. The characteristics of that industry -- computer components manufacture -- are growth, some established technology, and considerable empiricism. Obviously, these are the same characteristics displayed by the Petroleum Industry after World War II.

It seems likely that future industry-wide cooperative research groups will succeed in similar industries. Growth implies considerable funding, not strong competition, for diminishing markets. Some established technology is necessary so that the industry can agree on what it needs. Empiricism implies that there is room for some basic research work, the area that universities can cover best. Science policymakers need to consider industry characteristics in determining what kinds of cooperative efforts to support or encourage.

Potential Problems

Potential problems and conflicts in university/government lab/industry research cooperation seem to revolve around the following issues:

(1) Academic necessity to avoid secrecy and to publish. I would urge universities to try to avoid the problem by doing basic, publishable work. This type of work will be welcomed by many industrial groups. If the university or government lab must do contract research

work requiring secrecy, then they must be able to live with the downside consequences.

(2) Patents and exclusive vs. non-exclusive licenses. The non-industrial labs should not try to negotiate everything before the fact. Most companies recognize that the university must own the patents and would just like to be treated fairly. Granting an exclusive license with some penalty, like loss of exclusivity for not moving ahead, is a way to insure development. Problems in this area may be more severe for government laboratories.

(3) Conflicts of interest. These can be problems if the university faculty gets more involved with contract research than is good for the educational system. The solutions seem to me to reside with the institutions.

(4) Antitrust violations. Big companies will watch out for this. Universities and government labs should be alert, but it's not their problem. Current rules about cooperative research are workable and more lenient than in the past.

(5) Product liability suits against universities. My solution is for universities to stick to basic research and not to get involved with

products. If they do, then the rewards should be commensurate with the risks.

(6) Adverse public reaction to the involvement of universities in proprietary research. This problem is much like the previous one. They should not get involved in proprietary research unless they are ready to take the risk of public backlash.

Clearly this list doesn't contain all possible problems. However, I have yet to see a problem that couldn't be solved if the parties involved really wanted something to happen.

The Future of Industry/University Research Relations

Finally, what about the future? Most of the things that seem likely to happen will be evolutionary. "High tech" companies in areas like biotechnology, electronics, robotics, etc., will continue to want access to research. However, I believe we'll see a new trend in smaller companies wanting access to technology, as opposed to research. This is information that the faculty already has and that the companies can apply. For example, in the Midwest, some of the small machine shops will be interested in learning about robotics and automation. This suggests opportunities for the universities in the area of short courses, team consulting, and perhaps on-campus training of key company people. Rensselaer already has some programs in this area with local industries. I am sure that there are other programs in place as well.

Another trend is that the R&D giants are changing their organizational styles. They are moving towards fewer layers of supervision and more decision-making by engineers and scientists. Thus, there will be more emphasis on careers which depend on technical, as opposed to managerial, talents. These technologists will demand more access to university research.

The characteristics of future successful cooperation between industry and university or government laboratories will be the same as successful past cooperation. First, the arrangements must be mutually beneficial. If either party is not really committed, then the proposed program won't work. And the parties won't be committed without seeing some benefit to their institutions. Last, but not least, institutions work through individuals. If the individuals involved are not committed, then nothing will happen.

The Role of the Federal Government

The foregoing has suggested characteristics of success of some Federal programs in support of university/industry research cooperation. To summarize:

(1) Providing seed money. NSF grants which anticipate later industrial support appear to have worked well in the past. The new NSF Engineering Research Center program is in the same vein. NSF should be prepared to cease support of centers which are not gaining industrial support.

(2) Providing matching funds. Industry welcomes programs where their funds can be leveraged with Federal dollars. University programs, where the chances of proprietary advantage are relatively small, are easier to fit into tight R&D budgets if matching support to the university is available. Both the NSF Cooperative University-Industry Research Program and the PYI Program provide such support.

(3) Providing other incentives to industry to cooperate with universities. The R&D tax credits given for contract work at universities in the current law and the extension to gifts of equipment from industry to universities are programs which should have positive consequences.

(4) Providing direct support to universities. While the Federal Government supplies the bulk of support to university research, it needs to continue to be alert to the changing needs of those institutions. Future faculty needs are being addressed, in part, through the PYI

Program. Current and future equipment needs are also critical. Strong faculties with up-to-date equipment will not only attract research support from industry, but also supply the well-trained graduates that industry needs.

My testimony has also pointed out the complexity of the industrial research effort and how this causes difficulties with university relationships. The warning for science policymakers is that programs to encourage university/industry research cooperation, which are tightly specific and targeted, may fail because only a few relationships will fit the program. Thus, I would recommend general programs, flexibility, and a willingness to respond to needs uncovered by the cooperating participants themselves.

I have not highlighted new needs or recommended new programs. My perception is that the Federal Government is aware of the needs of the universities and their industrial partners. The programs which are in place at NSF appear to be working. However, as the mission agencies support more of the basic research load, we should be sure that NSF, or the agencies themselves, is alert to possibly changing university problems and the need to address them through new programs.

ADEQUACY OF TRAINING OF SCIENTISTS AND ENGINEERS

The specific question posed by Dr. Holmfeld to the IRI panel was: "Is industry obtaining people who have the proper training commensurate with their scientific discipline and level of academic achievements (e.g., B.S., M.S., Ph.D.)?".

My answer to the question is generally affirmative. My company hires 20-50 research engineers and scientists each year, mostly in traditional disciplines. We are satisfied that the B.S. engineers are well-trained in the fundamentals, that the M.S. graduates have learned specialized techniques of interest to us, and that the Ph.D.'s have learned the basics of carrying out original research.

Two related areas stand out as open for improvement. First, as technical horizons broaden, breadth of training becomes important. For example, B.S. chemical engineers who plan to work in biotechnology need almost all of their current training, plus a background in microbiology. If the same engineer plans to work in the computer chip industry, he or she will need some basic information about microelectronics. The questions of breadth are not easy ones, but I believe the universities are beginning to address them.

The related problem area is that of interdisciplinary teamwork. It is too much to ask that individuals have all the breadth necessary to successfully pursue today's research problems. Hence, industry's emphasis on research teams. Training on interdisciplinary teams appears to be missing in the qualifications of many of today's advanced-degree graduates. Here, the universities may not be moving as rapidly toward changes as industry would like.

A lurking problem, probably beyond the scope of today's hearing, is the adequacy of pre-college training in science and mathematics. The individuals who make their way into careers in research generally seek out good pre-college training or overcome the handicap of poor training. However, such training handicaps will make it difficult for the nation as a whole to compete in a highly technological world economy.

It is not clear to me what the Federal Government's role, if any, should be in solving the breadth question. However, continued emphasis, as in the Engineering Research Center Program, on interdisciplinary cooperative research, will certainly help university departments move beyond their disciplinary boundaries. Federal concern about the pre-college education problem must continue and grow more focused.

On balance, with emphasis on research support which recognizes the universities' unique roles as educators as well as research organizations, I believe we will continue to have access to an adequate supply of appropriately trained scientists and engineers.

KWM
4/23/85

K. W. McHenry, Jr.

Keith W. McHenry, Jr. is vice president, research and development, for Amoco Oil Company, a Standard Oil Company (Indiana) subsidiary. He is in charge of all R&D on process and products for domestic and international refining and marketing and of most work on processing future petroleum substitutes.

McHenry received a B.S. in chemical engineering from the University of Illinois and a Ph.D. in chemical engineering from Princeton University. His entire industrial career has been with Standard Oil Company (Indiana) and its subsidiaries. He is a member of the National Academy of Engineering, Chairman of the Industrial Advisory Board of the Engineering College of the University of Illinois at Chicago, a trustee of North Central College, and a member of the Board of Directors of the Industrial Research Institute (IRI). Previously, he chaired the University Relations Committee of IRI and has served on advisory committees at the University of Delaware and Princeton University.

4/23/85

PANEL DISCUSSION

Mr. **Brown** [as acting chairman]. Thank you, Dr. McHenry.

Mr. Stickel, let's start with the point that you made about the IRI Federal Science and Technology Committee and the work that they are doing with the Federal laboratories to enhance a closer cooperation. We have been interested in that problem for a number of years, beginning at least back when we developed the Stevenson-Wydner Act, which was aimed at encouraging that kind of interaction. You have indicated that you are interested in developing that, and I would like to have you expand a little bit on what you are doing and the progress you are making. We would like to keep abreast of that situation if we can.

Mr. **Stickel**. We have proposed a project that we hope will be initiated at an annual meeting next month. The project is to study the need for, and recommend the development of, appropriate linking mechanisms between industrial research management and the Federal research equivalents.

This has been stimulated by the improvements that we have been able to make in the industrial research and university relationships, and we have used that as a model to encourage us to try to get these links with the Federal labs. The purpose of the links will be to help leverage the Nation's Federal research investment for long-term economic return and potential commercial development, consistent with other national interests.

Briefly, I will mention some of the things we hope to achieve with this: First, a closer working relationship between the private sector and the Federal Government at policymaking levels to help assess the long-term and macro impact of Federal research investments on various aspects of national growth; second, specifically to stimulate industrial creativity where Federal funding is used in direct support of private sector research.

Another is by improving communication and understanding between the Federal Government and the private sector concerning the existence of Federal research results or new Federal programs of potential interest to the private sector; for example, the Presidential Young Investigator Awards that Dr. McHenry mentioned to aid in the university-industry interaction process.

These and some other recommendations are in a memorandum that we have that we would like to present to you if you are interested.

Mr. **Brown**. We would like to have it, yes.

Dr. **McHenry**. All right.

Dr. **Tinsley**. If I might——

Mr. **Brown**. Please go ahead.

Dr. **Tinsley**. Back when we started the committee, the IRI Government Laboratory Committee, we considered every alternative that we could think on how best to start to work together. We looked at a couple of models that had been tried: the one in New Mexico, where the two labs participated in a big statewide exposition. We looked at the possibility of trying to dump all the research results from the Government labs in a data base, index it, and have it accessed, as you can with a couple of private companies that now operate.

We considered several other alternatives and came up with what we think is the best one, and that is the one we are operating today, and that is having spotlights on various Government laboratories and having teams of about—what is it, Chuck, 50 people?—50 people, industrial people, visit the laboratories. I think this has been probably the most successful thing. I don't think there is any alternative to walking around, touching, smelling, feeling what is going on in the place.

Mr. **Brown**. Well, I don't think we have ever come up with any ideal plan for achieving a better interaction between the labs and the Government, and, I think, you may be correct that actual onsite visits by the people involved may be the best way to do it, although I am not sure how you can institutionalize that.

The process requires that you first have some entity that knows what is going on in the laboratory, another entity that knows what the needs of industry are, and a linkage between the two. Now, your team visitations can help do most of those things, most of all three of those parts. But that is sort of a temporary expedient, isn't it?

Dr. **Tinsley**. I am not sure. Of course, all the labs, with your bill, have an office of technology transfer or whatever they call it.

Mr. **Brown**. They are supposed to have, yes.

Dr. **Tinsley**. And these guys tend to know most of what is going on, and the way the thing is arranged, he will generally put together sort of a menu of things that are going on in that laboratory. That then goes to our membership, and that is the way people decide that they want to visit that particular laboratory and see about that particular science and technology.

Mr. **Brown**. Have you actually tried this team visit thing?

Dr. **Tinsley**. Oh, yes. We have been to Brookhaven and Argonne. There is one coming up at Battelle Northwest. We have been to Oak Ridge, Lawrence Livermore, and——

Mr. **Brown**. Lawrence Livermore and what else?

Dr. **Tinsley**. The National Center for Toxicological Research.

Mr. **Brown**. Do you stay away from the weapons labs?

Dr. **Tinsley**. These are all nonclassified visits.

Dr. **McHenry**. Let me just give you, if I may, an anecdotal piece of data here. Our laboratory is very close to Argonne. For many, many years we had only nodding acquaintance with the people there and what was going on. They were fully funded by the Federal Government. They really were not very interested in talking to us, and we were not very interested in talking to them. As a result of this IRI program and some very marked changes in the attitude of the people at Argonne, we have a couple of very successful programs going with them now where they are providing some equipment that we don't have and some technologies that we are not familiar with, and this is working very well.

So, I think, that the IRI program, at least, in that microcosm is working, and there is more cooperation between industry and the Government labs.

Mr. **Brown**. Well, of course, a large part of the success of this program depends upon the priority that the IRI gives it and the quality of the people that you have making these visits. How do you get convinced that it is important that you do this? We cannot pass a Federal law that does that for you.

Dr. **McHenry**. I think we become convinced when we see this menu that Dr. Tinsley was talking about of the various technologies that are available and begin to believe that these are really available, that the people there really want to work with us. I have no problem, then, sending my top-level people to go and look and talk and make arrangements.

Mr. **Brown**. We have found that just as the process requires you to be informed and motivated, the best results coming out of the Federal labs occur when the top management of the labs is aware and motivated of the importance of constructing this linkage. Have you found that to be a problem, or is the situation variable with regard to the laboratories?

Dr. **McHenry**. Well, I can only speak for a couple of them that we have worked with. We think that the situation is much improved and that the people in the labs are really very much interested in working with us.

Dr. **Tinsley**. The directors of the seven or so big multidiscipline laboratories are members and attend the IRI-Federal laboratory meetings, and several of them generally come to our annual meetings.

Mr. **Brown**. I think we ought to encourage that if we can. That certainly is a good way of creating some linkage.

Did I understand you to say that you considered the desirability of having some sort of a comprehensive computer-based data bank that would contain the programs, the research activities that are going on in the labs, and you came to the conclusion that that was not the best way to proceed here?

Mr. **Tinsley**. It was going to take time and money, and we were short on both. There was a sense of let's get on with something, and we didn't have a lot of money to spend to do it. So that is why we arrived at that.

Mr. **Brown**. Mr. Volkmer, do you have some good suggestions here?

Mr. **Volkmer**. They need a Federal grant. [Laughter.]

Mr. **Brown**. These people have more money than the Federal Government does. [Laughter.]

Mr. **Volkmer**. They don't have the deficits, do they?

I noted with interest the working arrangements industry has, like the University of Delaware with the center there, and we have an advisory committee. You were pushing, Mr. Stickel, the idea that you have public and private cooperation with the universities, and perhaps industrial advisory teams to do those types of things. Could that be carried any further, or should it be, as far as, let's say, taking NSF and their broad programs all together? Would that be imposing industry too much on the public sector? Does anybody want to tackle that?

Dr. **McHenry**. The IRI, through its University Relations Committee, has taken on an advisory role to the Engineering Directorate at NSF and has tried to give them advice on the types of programs that work and how university and industry can get along. So, to the extent that one part of NSF now has some advice from industrial research, that is going on. As to the Federal laboratories, several have developed industrial advisory groups to work with them and help them out in shaping their programs. So, I think, this is a trend that seems to be catching on.

Mr. **Volkmer**. As long as we have that trend, then the next question is, as one who is on the outside looking in, with some not necessarily concerns but wondering, and that is, when you have these advisory groups with you, the Federal labs or engineering department of NSF, is it advisable to try to get that research, whatever is being done, more focused on what will benefit industry?

Dr. **McHenry**. Certainly that is one of the goals, particularly the advisory groups that work with the universities, to try to get them to do the kinds of research that we can build on. I think industrial research people feel that we can do development work, and industry and universities can do basic work, and if we can get a match there so that their basic work feeds our development work, this is the most efficient way to operate. This is the thrust of the advisory groups.

Dr. **Volkmer**. But you wouldn't want the applied or application work being done at the university level?

Dr. **McHenry**. I think this gets to be a problem when universities try to do applied work because they quickly run out of criteria to judge the worth of it, because they do not have a profit motive or a market motive or something like that.

Mr. **Volkmer**. They don't have the personnel that are involved in those things, either. Personally, I think we are better off with staying in the basic research area, also.

Dr. **McHenry**. I think most people in industry would agree with that.

Mr. **Volkmer**. I have no further questions at the present time.

Mr. **Brown**. I wanted to explore just one other area briefly with you. You know, a part of the catchword of this renewed interest in improving our industrial productivity in this country has been the catchword of reducing adversarial and enhancing cooperative relationship between the various sectors here—Government, industry, universities. All of you gentlemen have indicated steps in that direction and a contribution to it.

One of the problems that has been the hardest to break down is the disciplinary or departmentalized nature of universities and the difficulty of breaking away from that into an interdisciplinary mode and into a mode of cooperation with industry. Of course, we don't want to press that too far because we don't want to lose the values from the disciplinarian, departmentalized approach of the universities.

I think several of you have spoken in complimentary terms of the Engineering Research Centers and the Cooperative University-Industry Research Program at NSF. Would I take it that you would encourage the continuation of both of those at some reasonable level, present level, higher level? Have you any comments as to whether we could benefit from putting more resources into that kind of operation, or are we at the proper level at the present time?

Dr. **McHenry**. I will let the others answer as well. My perception is that the levels on those programs are pretty good, that we certainly should not think about cutting them out because, as I said, they both serve a very good function.

I think the Engineering Research Centers have gotten off to a very good start, and they need to be continued to be supported to get them up to the level of 20 or 25 that are in the original proposal. The NSF Industry-University Cooperative Research Program is not moving, in my view, as fast as it could, but I don't think that means it should be stopped. I think it is a good program. I think it needs some more educational work to get people to take more advantage of it.

I would welcome my colleagues' saying anything they want to say.

Mr. BROWN. But I want to get a feel here from you, representing industry, as to whether or not the universities—and I am talking of primarily the large research universities—are making an adequate response to this need for enhancing their cooperation with industry and breaking down their disciplinary barriers to the degree that it may be useful to do so.

Dr. McHENRY. My perception is at the moment that they still have a ways to go; that the universities need to pay more attention to interdisciplinary programs; that a chemical engineering department in a school is likely to ignore the chemistry department next door, where the two of them could be working very profitably together.

Mr. BROWN. Yes.

Dr. McHENRY. I would hope that the Engineering Research Centers, as they grow, will dip in not only to cross engineering disciplines but also to cross into the other sciences, into physics and chemistry and biology if that is appropriate.

Mr. BROWN. Biology is a good example. The buzz word today is biotechnology, you know, and this is going to require that biology departments and engineering departments and probably chemistry and physics be much more interactive than they have been in the past.

Mr. VOLKMER. And botany.

Mr. BROWN. Botany, also. Botany is particularly important, because plant biotechnology is the area for——

Dr. McHENRY. Yes, sir; that is the first one that is likely to go fast.

Mr. BROWN. Can we track this? Can we measure the degree to which we are making progress in achieving goals in this area and do something to encourage continued progress as a matter of policy for the welfare of the country?

You know, we like to have indicators for these things, and it is very difficult to envision indicators for some of these more intangible areas.

Dr. McHENRY. It is perhaps something that IRI could look into. I don't have any——

Dr. TINSLEY. You ought to be able to measure it.

Mr. BROWN. Well, of course, the best way is to have capable expert observers who will go into the scene and make some measurement, make some judgment, really. If the IRI could engage in that kind of an occasional analysis, it might be very helpful. Of course, we would have to call you back to testify more often. [Laughter.]

Mr. Lujan, do you have any questions you would like to ask of this panel?

Mr. **Lujan**. Yes; I am very pleased with this project that you have of meshing the Federal Government and the private sector research through IRI, and I think that is very good.

One of the things that we are trying to do—I guess this is the final product of this Task Force on Science Policy—is how can we do it better? Should we have some guidelines? What should our policies be?

I am interested not from the standpoint of IRI but from the standpoint of your involvement in your specific companies, in how private industry decides how much to allocate, what areas to pursue, how does it all come out? What kind of science policy do you have in your own company? Maybe that is a little tough, but that is the question that we are asking ourselves as far as Federal R&D is concerned.

Dr. **Tinsley**. How much to spend? Of course, there is no right answer that I am aware of. We make that decision based primarily on two things, I would say, where we want to go, and the other serious consideration is, what is the room left for improvement or invention? Are we close to the theoretical limits of the process that we are running, or is there considerable margin yet to be attained, and if we don't attain it, someone else will?

I think the overwhelming force is where do you want to go, where do you want to be in that particular business 10, 15, even 20 years from now. Then once you decide that, then it is just a matter of, "OK, here is what it takes, here is how long, and here is what it costs."

Mr. **Lujan**. Any other suggestions?

Dr. **McHenry**. I would basically agree with that and only add that trying to do this in any mechanistic sort of way is very difficult and that there is a lot of intuition and experience and so on that goes into picking the research programs once you know what your goal is and where you are going, and that trying to use quantitative methods in this area is very difficult.

Mr. **Stickel**. I did include some words in my statement to this effect. Generally, from a company's standpoint, your chief executive officer and board of directors kind of direct a level of research funding, what they want to provide for as a future investment to the company. That varies slightly from year to year. But within that level, there are a lot of inputs to what should be worked on, and in many cases it starts at a very low-level researcher, and he submits what he sees with his expertise in his part of the business, programs that maybe he is asked to initiate by an operating part of the company or whatever. These things are reviewed at progressively higher levels in the company, and those that are more important during that period are selected.

I think one lesson we learned in industry is that you don't pick a project that has a longer life span than the business cycle, because sometimes it gets dropped out in the cycle. But the level of funding is generally what the board of directors and the chief executive want to invest in the future, and the programs are developed in an iterative fashion by all members of the staff from the low-level researchers and through the directors of research and into the operating areas of the company who sometimes have to support these funds.

Mr. **LUJAN**. Does that basically leave basic research to the universities, to the laboratories, to government?

Mr. **STICKEL**. Basic research in industry, the question was asked of the previous testifier, and I don't think we have the answer to how much of industrial research is basic, but we are suspecting it is a level between 5 and 8 percent. So there is very little basic research done by industry totally.

I know in my particular company it might have been at a 10 percent level 6 or 7 years ago, and it is probably at a 2 to 3 percent level right now.

Mr. **LUJAN**. Two or three percent of the research budget?

Mr. **STICKEL**. Of the total research, yes. So we are looking to the universities to supply us with basic research.

Mr. **LUJAN**. And I would agree with that. I think that is the direction that it ought to come from.

Mr. **VOLKMER**. Would the gentleman yield?

Mr. **LUJAN**. Certainly?

Mr. **VOLKMER**. I am a little intrigued by this. I would like to go back a little bit on this, in other words, how we develop that R&D budget. I am sure perhaps various companies have variations of it, but basically, you are looking at the same thing, which is a lot different from the way we do it, in a way.

In other words, you do it on almost a project-by-project basis, then. In other words, no one comes along, the board doesn't come along, or the chief executive, and say, "Here is $1.5 million or $3 million for research; now go out and do your thing." It is turned around and it is developed from the bottom and comes up, and then they approve. Is that correct, basically?

Mr. **STICKEL**. My experience, of course, with my own company and with others I work with, is that it is a common method of developing a research budget. There are many methods. When we are talking about industry, we are talking about everything from pharmaceutical to basic materials, so there are different methods.

Maybe Keith can comment on that.

Mr. **VOLKMER**. Well, do you also look at it—in other words, you are trying to develop X product, let's say, or an improvement in Y product, whatever it is. You look not only at what it is going to cost in your fiscal year, whatever it is, but the overall total period, do you not?

Mr. **STICKEL**. That is right.

Mr. **VOLKMER**. And the total period of development?

Mr. **STICKEL**. Exactly right.

Mr. **VOLKMER**. And the total cost of development over that period, that projection?

Mr. **STICKEL**. That is right. Dr. McHenry mentioned that it is hard to do an economic study of a research project, but companies do try—mine does—to do an economic analysis on every research project.

Mr. **VOLKMER**. By economic analysis, do you mean the inputs?

Mr. STICKEL. The inputs, the costs, and the potential return to determine——

Mr. VOLKMER. The eventual return over a period of years, also?

Mr. STICKEL. Yes.

Mr. VOLKMER. I yield back. Thank you very much.

Mr. LUJAN. One other question. Some reports say that the more the Government puts in, the less industry is going to put in. Let me ask Mr. Stickel, for example, let me take a real case and see whether that encouraged you to put in, to do more research or less research.

This steel initiative that Jay Keyworth came up with and said we ought to put $10 million in. After that, everybody started falling all over themselves to show support for that, to help out the poor steel industry. We put $6 million in one committee here. Another one, well, we went ahead and put in another $2 million.

Let me ask you your reaction to that. Would that have the effect of saying, "Hey, we have a good initiative here on the part of the Federal Government; let's step up our own?" Or does that say, "Well, the Government is going to do all of this; we can reduce our own involvement in this type of research?" What effect does that have on you?

Mr. STICKEL. With the so-called Keyworth initiative—and I think that is a good example—the research that was suggested—and this involved Argonne, I believe—was research that was going to cost so much for one company that they couldn't think of initiating it. I mean, we just don't have the funds for that type of work. With the Government's submitting so much funding, the steel companies that would be involved in supporting that had the incentive to put their share into it.

The same can happen with joint research efforts which are happening now. But that type of research, when you are talking about basic processes, is so expensive that the companies are reluctant during these periods to put that money into it. The Government's funding encouraged the industry commitments at that point. I think that may be a case that you will find in that type of initiative.

Mr. LUJAN. So is the way this whole steel initiative is going to work, that the Government is going to put in a certain basic amount—say, the $10 million—and then companies contribute to that for the research being done at Argonne? Or are you doing your own research elsewhere that may parallel or add to Argonne?

Mr. STICKEL. I think industry's commitment was going to be funding to put researchers actually at the Argonne Lab. I may be wrong on that, but I think that was it. They would actually be paying the researchers that would work along with the Federal researchers in the program.

Mr. LUJAN. So that it was a cumulative effort rather than a segregated one?

Mr. STICKEL. Exactly. It is a joint effort, the same type of effort we are encouraging with the universities.

Mr. LUJAN. What other industries do we have that would be along the same lines with the steel initiative and get the companies excited into doing something?

Mr. STICKEL. I think the agricultural industry is another example where it would help. There may be many more.

Mr. LUJAN. Batteries, probably. Are we doing that with batteries?

Mr. BROWN. There has been a battery research program in DOE for years.

Mr. LUJAN. But I am saying of companies interested in longer life batteries joining in with DOE on specific research. Of course, there you have the problem of the Federal Government then directing or saying what direction the research is going in, rather than somebody having a better idea.

Mr. STICKEL. We are hoping that, at the outset of these programs, the Federal labs will have enough input from the industrial partners that the research will be directed for the benefit of both.

Mr. LUJAN. Yes; most of what you were talking about, Dr. McHenry, a little while ago was more in the technology transfer area than in the basic research, when you talked about the laboratories. Is that correct?

Dr. MCHENRY. As far as the Federal laboratories were concerned, yes, I was thinking more of technology transfer, although the program that we have going with Argonne is one that is very basic. They are doing some very basic work in catalysis, and this is actually joint with Purdue University and Argonne and our company, and it is at a very basic level.

Mr. LUJAN. What about in technology transfer? When you go to the laboratory for some information as to the results of their research, do you bring something to put into the lunch bag, some of your own stuff, some of your own research that you might have done that says to the laboratories, we have done this; a quid pro quo?

Dr. MCHENRY. I think there is certainly some. I think these kinds of arrangements work the best when the two scientists or engineers involved become very close and begin to talk with each other about, this is what we find and this is what we find, and in that sense, it is important for industry to keep some basic research going, because you need to be able to talk the language of the people who are doing the work in either the Federal laboratory or the university.

Mr. LUJAN. At the basic research level, there is not as much of a problem to private industry to disclose their own findings. Am I correct in that?

Dr. MCHENRY. Absolutely.

Mr. LUJAN. So it lends itself to a better exchange.

Mr. STICKEL. With the program with the Argonne Lab with the Keyworth initiative, the initial part of the program is a transfer of technology from a steel company to the Argonne Lab, which has a basic computer model study of steel making. So that is actually put into the program as the initiator.

Mr. LUJAN. Are you concerned that some of the research that U.S. Steel has done that you may think is just really great, are you concerned that by going in with Argonne, you are giving up some of your secrets that are available, then, to your competitors?

Mr. STICKEL. Yes, it was a concern at the beginning. First we asked that it be excluded from the Freedom of Information Act because then even our foreign competitors could have gotten it.

Mr. LUJAN. Yes.

Mr. STICKEL. And then we asked that it be held as confidential except to those members who would be participating in the program.

Mr. LUJAN. Thank you.

Mr. BROWN. Gentlemen, I have reviewed very quickly this draft outline for your project on Federal/private sector interactions, and the stress you put on analysis of the linkages, there are a lot of very sticky problems there, and I don't think that even as distinguished a group as the IRI is going to come up with the final solutions, but it would be tremendously beneficial to us to have the benefits of your study, and I gather you are willing to share that with us.

We will look forward to receiving that. If you in your wisdom would care to explore some even broader problems than just the working linkages—a problem in the Federal Government, for example, is that there is no real overall Federal Government coordination of the various research programs, except at the level of the President, and I sometimes wonder if he knows what is going on. I am not speaking in a partisan way; this applies to any President.

The issue of whether we ought to have a better coordinating mechanism at the Federal level for science and technology such as a Department of Science and Technology, which George Keyworth seemed to have thought would be a good idea at one point, and which seemed to get some favorable reaction from private industry, we would appreciate any broad recommendations that would enhance the overall goal of better coordination of government-industry R&D on behalf of achieving national goals. I am very pleased to see the effort that you have made so far in that area.

I have no further questions, and unless someone else has, I think we will excuse you, with our thanks, and we will look forward to staying in touch with you for some additional input from you.

Dr. MCHENRY. Thank you very much.

Mr. BROWN. With that, the task force will be adjourned until 9 o'clock tomorrow morning.

[Whereupon, at 4:22 p.m., the task force recessed, to reconvene at 9 a.m., the following day, Wednesday, April 24, 1985.]

THE RELATIONSHIP OF INDUSTRIAL BASIC AND APPLIED RESEARCH TO GOVERNMENT SCIENCE POLICY

WEDNESDAY, APRIL 24, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 9:05 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. The meeting will come to order.

We begin the second day of our hearings on the relationship of industrial basic and applied research to Government science policy. We had a very fine hearing yesterday, and today we will begin with the academic overview.

PANEL: ACADEMIC OVERVIEW

Mr. Fuqua. We have Professor Griliches, Department of Economics at Harvard, and Prof. David Mowery, Social Sciences Department at Carnegie-Mellon.

Dr. Griliches, we will be glad to hear from you.

STATEMENT OF DR. ZVI GRILICHES, NATHANIEL ROPES PROFESSOR OF POLITICAL ECONOMY, DEPARTMENT OF ECONOMICS, HARVARD UNIVERSITY, CAMBRIDGE, MA

Dr. Griliches. Thank you very much. It is a pleasure and an honor to be here.

I have a prepared statement which I assume will go into the record, and I will just talk informally.

Mr. Fuqua. Yes. We will make the prepared statement a part of the record, and if you wish to summarize, that will be fine.

Dr. Griliches. Yes. I would rather talk informally about it.

I want to make four related comments or points for discussion. One of them is that I want to comment and retell what has happened to aggregate basic research in industry in the last two decades. Second, I want to describe a little bit the results of a recent study that I have done which underscores the importance of basic research to productivity growth in industry. Then I would like to make a few comments about how difficult it is, and why it is difficult, to produce conclusive evidence of the contribution of research to productivity given the state of our statistics.

Finally, I want to complain about the various current attempts to reduce the range and availability of statistics in this area, in the area of special interest to this committee.

Now, everybody knows, I think, more or less, that what has happened to R&D in industry has been that it has been basically flat in the seventies. It peaked in the midsixties, it was basically flat in the seventies, and it is only in recent years that it has picked up again in real terms, and much of the pickup has been associated with a rise in defense expenditures. I mean, as far as I can see, there has not been a large-scale increased recovery of R&D expenditures directed toward civilian ends in the economy.

Now, during the same time, basic research is a small fraction of total research in industry, something on the order of 3 percent or so. Basic research, in absolute numbers, peaked in 1966 and kept going down until the midseventies, falling from about $800 million to about $580 million in 1977 dollars in industry, and it did not rise above about the 1960 levels until recently. In that sense, I think we have had throughout these decades no real growth either in total R&D and a decline and only a very small recovery in basic R&D in industry. Moreover, we went through a very significant roller coaster, and we are still going through that, of having support for R&D rising into the midsixties and then dropping sharply into the seventies, and then recovery beginning currently somewhat. I would say that one of the real problems of U.S. science policy is how to provide a stable base of support for basic research both in industry and in universities, that there are sort of boom and bust times that keep going that are associated with swings in Government policy.

Now, should we worry about these kinds of numbers? I guess my basic feeling is that yes, we should. It is very difficult to produce any convincing numbers saying that because of this, the following has happened. In social science, our tools are reasonably blunt, and we don't have well-orchestrated experiments, so that all we can do is to look at the numbers and make some reasonable inferences.

I have recently done a rather large-scale study in which we have collected, with the help of the census and NSF, data for the 1,000 largest manufacturing corporations in the United States for the period from the late fifties through 1977. What I have been looking at is the relationship of productivity growth at the firm level to its R&D investments and, in particular, to its investments in basic research.

In this study, I find two major conclusions, I would say. One is that, indeed, productivity differences across firms and differences in the growth of productivity across time are related positively and significantly to the level of R&D expenditures.

Moreover, this relationship—that is, the relationship of productivity to R&D at the firm level—has not declined over time. That is, I find no evidence for the proposition that the effectiveness of R&D, or its fecundity, has declined over time in industry; that in some sense, rather, we are reaching the end of the frontier and we are running into sharply diminishing returns.

The other main finding which I was sort of surprised by is that if you look at basic research as compared to the rest of it, I find that it has a bigger effect on productivity differences and growth than other kinds of research; in fact, that interpreting the numbers that I put together would imply that the dollar spent on basic research is equivalent to spending between $2 to $5 on other kinds of research.

Now, this number is not inconsistent with earlier results found by Mansfield and Link, but mine is based on a much larger and more complete and more up-to-date sample.

Now, there are a number of problems. You come to somebody and say, "Look, this is such a good thing." You run into sort of the conceptual problem: "If this is such a good thing, why aren't they doing more of it? I mean, what is it?" There is sort of an inconsistency.

I go to the number, and I find that there is this high rate of return for R&D, there is this even higher rate of return for basic R&D, and on the other hand, R&D is not growing. So either I am wrong or they are wrong, or we don't really understand what is going on. I think there may be a little bit of all three.

But, I think, if I have to hazard a guess, I would make two points. One is that R&D is a very risky investment with a long horizon, which leads firms to be, by and large, more conservative, to expect a high rate of return before they are willing to invest much in this particular line of activity.

The second point is that, in particular, as far as basic research is concerned, it is the kind of activity which is likely to depreciate faster as far as a private firm is concerned, in the sense that because of its basic nature, it is done more openly; it is more available to the rest of the community. In that sense, it leaks out faster, and to the extent that there is something there, other firms can imitate it and erode whatever the position of an individual firm is faster. That kind of an erosion is a depreciation from the point of view of the firm in the sense that the firm, when it makes some kind of internal rate-of-return calculation, must take that into account.

But, on the other hand, it is not a depreciation from the social point of view, because we are, in fact, gaining from the fact that the knowledge is spreading out faster and being used by more people.

Now, the other finding of this study—and it is not inconsistent with other findings, with findings from other people—is that the impact of company dollars spent on R&D on company productivity is higher than R&D dollars financed by Federal contracts or grants to these companies. I am talking now about R&D performed in industry but financed either by companies or by Federal money.

Now, that is not all that surprising, because much of the direct output of federally financed R&D is sold back directly to the Government in forms of cost-plus items and, as a result, does not necessarily show up in the firm's own productivity as we can conventionally measure.

Now, that brings me to my third point, which is the difficulty of actually tracing or measuring the effect of especially Government dollars, research dollars, on productivity. There are at least two major problems with trying to do the sort of thing that I tried to do, or some of us tried to do, which is to go to the statistics and try to find the traces and say, here we spent so much on R&D; where is the product, and how can you compute the rate of return?

Well, in fact, if you are looking at aggregate productivity measures, you are looking for the effects of Government-sponsored R&D. You are looking for something which is, by and large, not there, because most of Government R&D is spent directly on things which do not show up in the productivity accounts. They do not show up because we do not know how to measure their output.

Most Government-supported R&D is spent on defense and is spent on space. Whatever one's opinion is about the value of these expenditures, within the national account framework, there is no way in which they can reflect success in those activities. So whether we land on the Moon or whether the mission is aborted and fails shows up essentially the same in GNP.

Government product we measure by input, and therefore, there is no way in which productivity, either in the sense that we actually get somewhere in space or that we have better defense, can, in fact, be detected in the numbers as they are.

Even something that could be detected is not in there in the way we measure things. If you think about the support of health expenditures, which is another major component of Federal expenditures, if we manage to conquer a particular disease and people are able to work more, to a first approximation, we are going to have a rise in GNP; we are going to have a rise in man-hours; and we are going to have no change in productivity per man-hour.

So it is not going to show up there unless we have a calculus which actually measures how much more we are getting out of a given labor force or how much more we are getting out of a given population. That is not in the national account as it is currently conceived. That is one part of things.

Now, the other part of it is that things which, in a sense, are products where you could do something, we also do not do very well. Another large component of research output is better technology or better products.

We do not have very good tools, and the official agencies have not had enough support in doing research on the problem of how to measure the output of the computer industry, of the telecommunications industry, of the semiconductor industry, in which new products are appearing every day, and when we measure productivity, we are measuring their sale. We are defining output as sales being divided by some price index.

Well, these price indices are no good for this purpose, by and large. I am sure you have been told that a dozen times. Well, I will tell you again. In the official accounts, the BLS and the Department of Commerce have thrown up their hands and said, "We don't know how to measure the price of computers, and therefore, there has been no decline in the price of computers recorded in the data since 1950." So the whole computer revolution is not in an output series. There is expansion to the extent that the dollar amount in business has grown, but the fact that you are getting more for your dollar out of that industry is not in the national accounts.

Given that, it is rather difficult to come back to you and say, "Here, I can show to you that this research is having large productivity." I can tell you where it is disappearing, but it is rather difficult to measure that.

Now, the last point that I really want to, in a sense, provoke discussion or complain about is that looking at your agenda, you have a very good agenda with lots of important and interesting questions. But one of the questions that isn't on your agenda is "Where will the answers come from?"

You know, these are interesting questions, but how are you going to generate answers to them which are in some way somewhat more scientific answers rather than just a procession of people who are going to come and tell you, "This is good stuff; support it; I believe in it; I feel it in my guts"?

We all know that basic research is important. You cannot get conclusive evidence, but if you want a more serious examination of data—the time to ask what parts pay off, what has happened, where is the dollar going, who is spending what on where, and how are things affected?—you need a data base. You need people who are actually looking at the numbers and people who are criticizing both the numbers and the conclusions and studying the topic. Now, right now, we are going through periods in which, instead of adding to the knowledge base on the topic of this level of importance, we are in fact reducing; we are falling further behind in trying to understand what is going on. I will just give you two examples of what I mean.

One of the few measures available for studying technological change and inventiveness and innovation in this economy is patent statistics. Now, there are lots of problems with patent statistics in terms of interpreting the numbers. But, in fact, it is the only piece of data that sort of happens close to the invention process.

The other thing that we know about are the moneys that are spent, allowing for what accountants do to those numbers. But that is about inputs. We have very little direct measurement of output of the invention technological process. Everything else is quite a long way removed.

When we talk about productivity, we are talking about things that are happening 5, 10 years later in any technological process, which is very difficult to make connections to.

Now, in recent years, the Patent Office data have become computerized. It is in fact possible to start studying it. One previous large study that was done was done by the late Prof. Jacob Schmuckler of the University of Minnesota, who spent 2 years in the basement of the Patent Office trying to transcribe cards and accumulate statistics by hand.

However, it is not possible to do these things without worrying about how the data are put together, how they are cleaned, how they are organized. Within the Patent Office there was a small office called Office of Technology Assessment and Forecasts whose job, in a sense, was to try to make the patent data usable. It put out various publications. It tried to organize statistics. Some of them are better; some of them are worse. I am not going to argue that everything that they did was the world's greatest stuff. They were not that well staffed. But they were trying to make that data base available so that if you wanted to find out today whether or not the rate of patent in semiconductors in the United States has gone up or gone down, whether the Japanese are increasing their share, or whether the Taiwanese have actually come in or something, you could actually get those numbers from them in a reasonable fashion.

Last week they were abolished as an office, without anything in particular—you know, whatever the Patent Office was told, to cut its budget by 10 percent, and within 2 weeks, the office disappeared.

The effort that goes into building up a data base and to building up programming skills and to trying actually to be able to manipulate—it is an incredible data set of hundreds of thousands of patents. In making it accessible, the notion is that private industry will step in and do this sort of thing. Private industry will step in and will sell you a xerox copy of a patent for $5. It will not maintain a large general data base in the same way.

Information is really the primary example of a public good in which it is very difficult for industry to make a living by selling it retail, and that is what you see. Software is another example of that kind of thing, and so you don't really produce these things.

The final point I wanted to make is that there was another office, one of the few places in the Government support of research which worried about supporting research or research. This is on the topics that deal with this committee's interest today—what is happening to industrial R&D, what is happening to the competitiveness of R&D, what is happening to science, how do you measure, how do you get better measurements?

That was an office in the National Science Foundation called the Office for Policy Research Analysis. Under the label of policy research analysis, in fact it was earmarking and providing money for study of technological change of R&D and the relationship of R&D to productivity. In a recent rearrangement, its budget has been cut by more than half.

Now, this is a certain amount of special pleading, but what I am trying to say is that in policy analysis, just like in economics, and in science policy analysis, also, there is no such thing as a free lunch. You want to know what should be the right policy, and there has got to be a basis, a scientific basis, a data basis, for analyzing, for trying to find out what is going on and then trying to think about whether it makes sense or it doesn't make sense.

I just have a feeling that that part of it is not being appreciated enough, particularly in the current efforts to reduce both the support for data collection and the availability of data to the public.

I will stop here.

[The prepared statement of Dr. Griliches follows:]

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April 24, 1985

Testimony of ZVI GRILICHES before the Task Force of the Committee on Science and Technology. Hearing on "The Relationship of Industrial Basic and Applied Research to Government Science Policy."

My name is Zvi Griliches. I am Nathaniel Ropes Professor of Political Economy at Harvard University and Director of the Program of Productivity and Technical Change Studies at the National Bureau of Economic Research. I am also a member of the National Academy of Sciences Committee on Science, Engineering and Public Policy. I have spent much of my professional life studying technical change and the role of R&D expenditures in it and I have recently completed a study of the productivity growth of major U.S. corporations in the 1970's with a special emphasis on the role of basic research in it.

In the brief time available to me I would like first to make some general remarks on what has happened to basic research in industry in the last two decades. Second, I will summarize and discuss the results of my study which underscore the importance of basic research to productivity growth. Third, I shall discuss some of the problems that arise in trying to measure the social returns to federally funded R&D expenditures, and fourth, and finally, I will complain about current attempts to reduce or eliminate data gathering and research support devoted to the study of these topics, topics that are of special interest to your Committee.

Zvi Griliches April 24, 1985

1. Total R&D expenditures in industry peaked (in constant dollars) in the mid-1960's and stayed essentially flat throughout the seventies. Relative to sales in industry, to the rest of the economy or the rest of the world, these expenditures fell behind significantly. In part this was related to a significant decline in the share supported by federal funds which fell from over a half of the total in the mid sixties to less than a third currently. The impact of these changes on basic research in industry was even more drastic. It fell absolutely from a peak of $813 million in 1966 (in 1977 dollars) to a trough of $581 million in 1975 and did not surpass the 1960's levels until the early 1980's. Federal support of basic research in industry fell from over 30 percent in the mid-sixties to less than 20 percent today. While there has been some recovery in both total and basic R&D in industry in recent years, almost all of it is associated with the rise in defense spending and its ultimate impact on the productivity of the civilian economy is in some doubt. In fact, the major swings in R&D and in federal R&D support for it can be associated with large swings in federal space (the peak in the sixties and the decline in the seventies) and defense programs. One of the real problems of US. science policy is how to provide a stable base of support for basic research in both industry and universities. At the moment only four percent of the total federal expenditures on R&D are devoted to the support of "general science."

2. Should we worry about these trends? I think we should. I have recently completed a first analysis of a newly collected large data set covering the productivity experience of most of the large U.S. manufacturing corporations between 1966 and 1977. It is based on a match of individual firm R&D reports to the NSF in different years with their comparable sales, employment, and

capital reports to the Census. This matching and all the basic calculations were performed for me by the Census (with financial support from the NSF) preserving the confidentiality of the individual firm responses. The data base so created is unique in bringing together information on over a thousand firms for over a decade on a large number of interesting economic measurements.

The first results of our analyses of these data, available as NBER Working Paper #1547, include several findings of interest: (a) I find that both differences in levels of productivity across firms at a point in time and differences in the rate of growth of productivity amongst them are related, positively and significantly, to their R&D expenditures and that this relationship has not declined over time. That is, I find no strong evidence for the proposition that the effectiveness or fecundity of R&D is waning, that we are reaching the end of this frontier. (b) As far as different kinds of R&D are concerned, our results indicate strongly that basic research is a more "powerful" generator of productivity differences and growth, in the sense that a dollar spent on basic research is equivalent to spending between two to five dollars on applied research or development. This last finding is consistent with similar earlier results obtained by Mansfield and Link based on smaller and less complete samples.

There are a number of technical problems with and reservations about such findings which are discussed at some length in the original report. Here I want to highlight only one of them: If R&D, and especially its basic component, are so effective why are firms not doing more of it? I do not have a good answer to this question, at least not on the basis of the data available to me, but I will hazard two guesses: First, R&D, and in particular basic R&D, is a very risky investment with a very long horizon which leads firms to be more conservative and require higher expected returns before they are willing to invest much more in such activities. And second, the results of such activities are likely to "depreciate" faster, in the sense that the advantage gained by one firm as the result of its own research efforts may erode rather quickly as other firms begin to imitate it and develop alternative versions of the new products or processes. This is especially true of basic research, where the results may be of more general use and hence leak out faster and wider and where the time to fruition is much longer. Thus, it may not be surprising if the expected private rate of depreciation of such investments is rather high. In addition, firms may be imposing too high an internal rate of return criterion on R&D projects. While it is true that they are risky, many of these risks are independent of each other and hence "poolable," the whole program being much less risky than its individual components.

Another finding of this study is the larger effect of company financed R&D expenditures on company productivity than that of federally financed R&D expenditures. This, perhaps, is not all that surprising. Most of the direct output of federal research dollars is sold back to the government at "cost plus" and is unlikely to show up as an increase in the firm's own productivity. This brings me, however, to the third point that I want to make: the difficulties in measuring the output of research dollars, especially the type of research that is supported by federal moneys.

3. When we look for the effects of publicly funded R&D expenditures on aggregate productivity measures we may be looking for something that is largely not even there -- for reasons having to do both with the nature of much of R&D and the nature of our GNP and productivity accounts. There are at least two problems here: First, most of the R&D "product" is sold to the public

sector. It consists of research on defense and space exploration, for which no adequate market valuation exists. By accounting convention, these "outputs" are measured by costs, resulting in zero contribution to measured productivity, by definition. (This is true for the bulk of defense and space research, which is contract research with an end-product of blueprints, formulae, or prototypes. It is also largely true for the research components of the "hardware" sold to the government, because of the lack of appropriate price indexes by which to deflate such expenditures.) For example, whether the moon landing was successful or not, the effect on measured GNP would have been the same. The contribution of the space effort is measured by the inputs into it, the cost of man-hours and hardware, and not by the success of these efforts. Similarly whether the MX missile is better than what it is supposed to replace and whether our security situation has improved or deteriorated as the result of research expenditures on military technology will not show up in the growth of national productivity as it is currently measured.

Or, taking another example, consider public research expenditures on health that lead to increased life expectancy and a lower incidence of some disease. These also would not show up in the current productivity accounts. Currently, such an improvement would raise both measured GNP and the hours worked by the labor force, leaving "productivity" (output per man-hour) largely unchanged. The contribution of such expenditures could be computed if we evaluated the changes in the "productivity" of obtaining hours of work from a given population. But that kind of calculation is not within the framework of the national-income accounts as they are currently constructed.

Second, much of the product of private R&D investments is in the form of new commodities or improvements in the qualities of old commodities. Whether this product shows up in "real" GNP (in constant prices) depends on what happens to the price indexes with which the current net output of the particular industry is deflated. If the price indexes were to recognize these improvements in "quality" fully, the resulting real-GNP measures would reflect the social product of this research. But that is unlikely. If the price indexes fail to reflect these quality improvements, only the private product will show up in the real accounts -- to the extent that firms succeeded in appropriating it via higher prices for the newer higher quality products.

If some of these unmeasured improvements are attached to products used in turn as inputs into the production of other private products, their contribution will show up in the productivity measures of the industries that purchased them. Thus, for example, though the contribution of research on improving the performance of farm tractors may not show up in the output-input account of the tractor industry, it will have an effect on measured productivity in agriculture. But many new products are sold directly to consumers, and the improvements associated with their use are not caught in the conventional measures of GNP or consumption per capita. Examples are time-savers like pocket calculators or the whole air-transport industry: The fact that one can get to the West Coast from the East Coast in half the time required 25 years ago leaves hardly a trace in the national productivity accounts.

In an earlier paper ("Research Expenditures and Growth Accounting," 1973) I tried to guess the extent of this problem. By looking in some detail at the sources of funds and the announced uses of them, I concluded that in 1970, out of the $27 billion or so identified as "research and development" expenditures, half could be attributed to defense and space activities. Of the remainder, about $11 billion could be thought of as having a potential impact on aggregate productivity. These $11 billion consisted of $9.5 billion spent in industrial research; about $0.3 billion in intramural federal research; and $1.3 billion in research in universities, institutes, and similar organizations. More recent data do not indicate any significant change in the allocation of R&D expenditures. Significantly less than a half of the total R&D expenditures in the economy are likely to leave traces of their direct contribution in the national productivity accounts. This does not mean that these expenditures are necessarily unproductive, only that we have no good way of measuring their effects. This brings me to my last point: The current lack of appreciation and support for data collection and research in this area.

4. Because research "output" is rarely sold in the market or observed directly, it is rather difficult to collect and analyze relevant statistics about it. We would like to know who does it, to what extent, and in which direction. The Bureau of the Census collects R&D data from companies on behalf of the NSF. These data are imperfect in part because companies now are so variegated and because not enough detail is collected on what companies are actually spending their R&D moneys. The whole effort is also quite underfunded. The unit at the Census dealing with these data is small and overextended and because of budget cuts the collection of the detail on basic vs. total R&D split and on the allocation to product fields is being done only in alternate years with very little effort devoted to studying how these measures could be improved.

On the output side, one of the few quantitative indicators of inventive activity available to us are patent counts and the more detailed information contained in the patent documents themselves. Over the last decade a small office within the Patent Office, the Office of Technology Assessment and Forecast, has struggled valiantly to make some of these data available to researchers and analysts. Data are not usable in raw form. They have to be organized, computer programs have to be designed and written, and access procedures have to be developed. OTAF has made possible the study of patent statistics in the modern age and provided tools for tracking what is happening in specific technologies and to the U.S. competitive position in them. This week it is being abolished as part of an economy move at the Patent Office (another example of penny-wise and pound-foolish) and the overall drive by this administration to reduce the amount of data collected and made available by various governmental agencies. The notion that private sector information firms will step in and take over this role ignores the public good aspect of information as a product and the large economies of scale in developing data management and data access techniques. It seems that this administration not only does not want to know the consequences of its various economic policies but is also trying to see to it that nobody else will find out.

The Committee's "Agenda for a study of government science policy" is full of interesting and important questions. One of the questions it does not ask, however, is "Where will the answers come from?". Where is the factual base and the scientific expertise to be found to answer such questions? One of the few units in the federal government that saw as its mission to study such questions and to support research targeted at trying to produce answers to your "Agenda," the Policy Research Analysis unit of the NSF, has just had its budget cut by more than a half. If these questions are important, if we want to understand more about our economy, about science and technology, and about their impact on industry and on our lives in general, we will need to figure out ways of encouraging and supporting the study of such questions and the collection of data on the relevant aspects of it. If the decisions are to be better informed, the relevant information has to be collected, processed and analyzed, and the whole endeavour has somehow to be financed. In economics we say that there is no such thing as a free lunch. My guess is that there is not one in policy analysis and public decision making either.

Mr. **Fuqua**. Thank you, sir.
Dr. Mowery?

STATEMENT OF DR. DAVID C. MOWERY, ASSISTANT PROFESSOR OF ECONOMICS AND SOCIAL SCIENCES, CARNEGIE-MELLON UNIVERSITY, PITTSBURGH, PA; AND RESEARCH ASSOCIATE, STANFORD UNIVERSITY CENTER FOR ECONOMIC POLICY RESEARCH, STANFORD, CA

Dr. **Mowery**. Thank you, sir.

I also would like to have my statement submitted into the record, and I will try to summarize the main points briefly here.

I would like to talk, really, about three major points. One is to simply consider the existing rationale from economic theory for the Federal support of basic research and to critique its adequacy for achieving some goals of improving innovative performance and U.S. industrial competitiveness, and then move on to suggest a couple of areas in which the management of Federal basic research allocation and organization could benefit from the experiences of private industry. In so doing, I would like to second as strongly as I can Dr. Griliches' comments about the current climate and the current treatment of data collection and research support in these areas. I think that one can add two or three other important programs of data collection that have been either severely reduced or abolished within the last 3 or 4 years, and I think we are simply shooting ourselves in the feet. The necessary information for making important decisions on science policy, on the treatment of innovation within industry, simply is being undercut and is being eroded by some of these policies.

The existing rationale, I would suggest, for Federal support of basic research really relies on an argument raised by Professor Griliches referring to the low appropriability or the limited ability of performers of basic research to reap the benefits of this basic research. Certainly this is the key problem resulting from this market failure, and this has been stated quite forcefully in recent documents from the Office of Management and Budget, notably the fiscal year 1983 special analysis of R&D. The key problem is an undersupply, it is believed, of basic research due to this inability to reap the full benefits.

I would suggest that this rationale, while certainly correct and unobjectionable on a theoretical basis, really is an incomplete rationale for Federal support of research and Federal support of basic research with a view toward improving economic performance and competitiveness. I think it is incomplete.

The real economic impact of research and development, the productivity impact of basic research of which Professor Griliches spoke, is really reaped through adoption and diffusion of the information, adoption and diffusion of the innovations resulting from basic and fundamental applied research, and indeed, Federal policy historically has paid relatively little if any attention to support of the diffusion process within the innovation process.

I think if you look at other nations' scientific and/or industrial policy, notably those of Japan in industries like computers or robotics, you will see that support of research is combined in many cases with policies designed to support the more rapid diffusion and adoption of the innovations resulting from this research. So I think it is not sufficient to look only at the supply of basic R&D or even fundamental applied research. We really have to think as well about how this is being utilized and how this is being adopted, and the payoff comes from the adoption and diffusion.

As I suggest, then, our existing theory is really somewhat incomplete as a guide for policy, and I think that the empirical studies that have come out, the studies of existing economic data that have come out within the last 10 or 15 years have really advanced our understanding considerably of the relationships between publicly and privately funded R&D, between perhaps the R&D tax credit of 1981 and the response of private R&D spending and a range of other relationships at the aggregate level.

At sort of a more detailed level, at the sectoral or firm level, our understanding is much less firm; our grasp on these issues is much less precise, partly because of the fact that the theory and the empirical work have really moved, have operated in different spheres to some extent. We don't have as solid a set of theoretical explanations for the relationships that, among others, Drs. Griliches, Mansfield, and Shure have uncovered as we would like, and it is really in this area that the current climate of research support and data collection, I think, is most crippling.

In the relative absence, then, of well-developed firm and sectoral theories of the R&D investment decisionmaking process, I think that the lessons that the public sector R&D management process can learn, or the conclusions that we might draw from the behavior of firms, from the management of industrial research, are fairly general and deal more with the process and the structure of industrial research, particularly in basic research.

I think, really, there are two key points of contrast between the management of industrial and Federal basic research, in particular. I think in many ways the decisionmaking process in its general characteristics on what projects are supported in these two sectors is fairly similar. There is a great deal of reliance—and here I am talking about basic research and fundamental applied research—on peer review, in many cases academic advisors operating in conjunction with both industrial labs and in many cases with major Federal extramural research supporters like the National Institutes of Health or the National Science Foundation, so that in some ways the evaluation processes in these two spheres are similar.

But there are, I think, two critical differences. The first is that within industry we see, in the most effectively managed industrial labs, a much more consistent and ongoing attempt to enforce internal competition among areas or among candidates for basic research support across the board within the basic research budget of a given industrial lab or company. That is to say that within a fixed basic research budget, a wide range of projects, a wide range of areas of scientific research compete for the dollar. I think that we do not find a comparably comprehensive review across the board of competing candidates for Federal basic research expenditures. We really do not find, either in the Executive or in the congressional budget review or allocation processes, a comprehensive review across the board of the full range of Federal basic research funding priorities. As I say, this applies both to the executive and the congressional branches. The Office of Management and Budget does conduct the across-the-board cross-cut of R&D within the annual budget review, but this is really a comparison of agency budgets more than a comprehensive examination of Federal basic research priorities.

I would suggest that the exercise that was conducted by the Office of Science and Technology Policy within the last couple of years which attempted to conduct something like this type of review within the executive branch might be strengthened, might be staffed more fully and carried out on a more regular basis, and I think such an exercise within the executive branch should be extended to incorporate defense basic research funding as well, since this is a large—around 12 percent of the total Federal basic research budget—share of this budget, and it is, I would suspect, likely to increase or certainly stay at roughly that level. So I would like to see the Federal process draw on the industry experience in this regard, making the review more comprehensive and enforcing greater competition among research areas.

I think, on Capitol Hill, the fragmentation of the basic research resource allocation process is, if anything, greater. I think that this has the effect to some extent of conceding the initiative to the executive branch in setting priorities in basic research, and I think that something like a task force or special subcommittee of the House or Senate Budget Committees, for example, could also be enlisted to conduct such a comprehensive review, perhaps working with the Office of Technology Assessment or outside bodies such as the National Academies of Sciences or Engineering. I don't want to suggest that a sort of Cabinet-level Department of Science is necessary for this type of exercise. I think that such a reorganization is neither necessary nor necessarily sufficient to bring about such a comprehensive review, and indeed, the existing sort of pluralistic and decentralized structure of research management might be preserved while bringing about a more comprehensive process of review of budgetary priorities.

The second point and second area, I think, in which Federal basic research management and organization might draw on the experiences of industry is in the importance of maintaining stronger linkages between basic and fundamental applied research. I think if you look at the organization and at the histories of the most successful industrial performers of basic research, you find a consistent strong attempt to maintain links between the basic and the more applied research functions. In fact, rather than innovation proceeding in sort of a one-way manner from basic research through applied to development work, these are interactive. There are flows of information and personnel back and forth among these various spheres of activity, and if you look at organizations like Bell Labs, DuPont to some extent, you will find a great deal of effort is taken to locate people performing basic research physically next to people performing fundamental applied research because of the importance of supporting these links for ensuring a high payoff to the basic research investment.

I think that the implications of this for Federal R&D management, for Federal basic R&D spending, are fairly straightforward and really are reinforced by looking at one of the most successful agencies in this area, that being the National Aeronautics and Space Administration. NASA has long been involved in working closely with industry in supporting both basic and so-called gray area or fundamental applied research, and I think that judging from the results, certainly the strong competitive performance of the industry benefiting from NASA aeronautics R&T, that this is a model that merits wider application within the Federal science policy sphere.

I think that there are a number of ways of bringing this about, possibly again drawing from the Japanese example, sliding scales of matching funding for industrial or university-industry laboratories and the performance of both basic and more fundamental applied research. Alternatively, the national labs or the National Bureau of Standards are other good institutional vehicles for bringing about a division of labor between the public and private sectors in the performance of basic and fundamental applied research that supports rather than tries to build a Chinese wall between the basic and applied research interaction.

Those are the main points I would like to make, and I appreciate your taking the time and inviting me to appear. Thank you.

[The prepared statement of Dr. Mowery follows:]

Federal and Industrial Basic and Applied R&D: Testimony of David C. Mowery before the Science Policy Task Force of the Committee on Science and Technology, U.S. House of Representatives, April 24, 1985[1]

It is a pleasure to testify before this Task Force, whose activities during this Congress should enhance our understanding of what is an exceedingly complex and increasingly important area of policy, the organization and management of Federal science policy. My remarks do not consider the empirical analyses of the impact of R&D investment on productivity, the relationship between publicly and privately funded R&D, or the effects of the 1981 R&D tax credit, that have been carried out thoroughly and effectively by these and other scholars. Instead, I would like to focus on the basis in economic theory for Federal science policy, discussing the strengths and weaknesses of this analysis, and use this discussion as the basis for a brief assessment of some ways in which the management and organization of Federal R&D might benefit from the experiences of private sector R&D managers and institutions. My premise is easily summarized: the total size of our national R&D investment, defined either in absolute terms or as a share of Gross National Product, almost certainly is less significant in predicting the economic payoff from this investment than is the intersectoral distribution and institutional organization of this R&D investment. Throughout my remarks, I should also note, I am concerned primarily with the economic impact of public and private R&D investment. This criterion is by no means the only or the most appropriate basis for evaluating Federal science policy. Nonetheless, it is the dimension of this policy framework to which I am best qualified to speak.

The theoretical model of R&D investment that underpins the case for public support of such investment rests on the assumption that the fruits of research, particularly fundamental and basic research, are not easily appropriated by the performer of such research. In other words, the social returns to investments in research are likely to exceed greatly the private returns accruing to the original investor in research and development. As a result, the supply of such research is insufficient, from a societal point of view. The prescription for this market failure is public support for basic research. Hence the pronouncement of Special Analysis K of the 1983 Presidential budget document that

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> ...the Government should focus its direct R.&D. support on those areas where there is substantial prospect for significant economic gain to the Nation, but where the private sector is unlikely to invest adequately in the national interest because the benefits, in large measure, are not immediately 'appropriable' by individual firms. Thus, for example, the Federal Government supports basic research across all scientific disciplines but limits its spending on technology development to technologies requiring a long period of initial development, such as fusion power, where the risk is high but the payoff to the Nation is potentially large. This strategy is reflected in the funding for R.&D. to meet national needs in the 1983 budget.(p. 4, Special Analysis K, Budget of the United States Government, Fiscal 1983.)

While this analysis is beyond reproach as economic theory, it is a weak guide for the formulation of policies aimed at improving the innovative performance of the economy via public support of R&D. The key issue for this purpose surely is the utilization of the results of R&D, rather than the supply of research results. The diffusion and adoption of new technologies, rather than solely their generation, are neglected, yet critical, dimensions of science policy for economic performance and international competitiveness. In other words, many of the stated goals of Federal R&D policy might better be pursued through a systematic effort to aid in the diffusion of innovations.[2] Indeed, a striking characteristic of Japanese industrial policy in such sectors as robotics and computers is the support provided for the adoption and diffusion of new technologies.

The theoretical analysis of the economics of R&D investment thus is deficient for many policy purposes in its austerity and focus on the supply, rather than the utilization, of R&D results. The empirical analyses of these phenomena, however, have yielded important findings for policy. The scholarly labors of Mansfield, Griliches, Scherer and others have shed considerable light on such issues as the relationship between productivity growth and investment in basic research, and the relationship between publicly funded and privately funded research within the firm. Nonetheless, theoretical explanations for these findings are not fully developed. These aggregate empirical findings accordingly provide incomplete guidance for science policy formulation, especially on a sectoral basis. It is unlikely, for example, that all areas of basic research investment yield a comparable productivity impact; nor is the observed complementarity between publicly and privately funded research likely to be equally strong and significant in all Federal programs or in all industries receiving such funding. The findings of these studies are important and useful to the formulation of science policy, but more work is needed in order to identify policies to improve U.S. innovative performance. Research aimed at linking the empirical and theoretical spheres of this body of analysis, ideally on an industry- or firm-specific basis, is required for these policy issues to be better understood. The negative attitude toward data collection and research support in this general area that has been evidenced by this Administration therefore is disquieting, inasmuch as it is depriving scholars and policymakers alike of the analytic insights that are necessary to the formulation of science policy that can aid U.S. competitiveness. Decisions on these issues must and will be reached; in the absence of scholarly analysis, however, they will needlessly be less well informed.

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[2] See Paul A. David, "New Technology Diffusion, Public Policy, and Industrial Competitiveness," presented at the Symposium on Economics and Technology, Stanford University, March 17-19, 1985.

Reflecting the fact that more disaggregate analyses of industrial research and development have been limited in scope and coverage, our understanding of the decisionmaking processes underlying investments in basic and applied research within industry is modest. The lessons for Federal R&D policy of industrial research management practices therefore lie more in the characteristics of this decisionmaking process and the organization of research institutions, rather than in the application to Federal science policy of specific evaluation techniques. While quantitative models of research project evaluation may serve a useful function in development projects, where uncertainties are lower and outcomes more predictable, in most cases they do not play a major role in the decisions underlying basic and fundamental applied research investment within industry. Indeed, as Professor Mansfield and his colleagues demonstrated in an earlier study, even the quantitative evaluations of costs and project duration employed within industry for development projects frequently are unreliable.[3]

Partly as a result of the limited reliability of such quantitative techniques, the procedures employed within the private sector for the evaluation and management of basic research closely resemble those seen in such major extramural research agencies as the National Institutes of Health or the

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[3] See "An Econometric Analysis of Development Costs," in E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, and F. Husic, The Production and Application of New Industrial Technology (W. W. Norton, 1977).

National Science Foundation. In both sectors, peer review and the judgment of informed and experienced participants are central. Major industrial research laboratories involved in basic or fundamental research frequently rely on a group of external scientists, in most cases drawn from academia, for evaluation of the merits of various areas of intellectual endeavor--the same is true of many of the major Federal performers of basic research. However, there are at least two generic principles of evaluation and organization within industrial research laboratories that have considerable promise for application to Federal science policy. These principles are those of internal competition for funds among different areas of scientific endeavor, and the support of strong linkages between basic and applied research.

Fundamental to the decisionmaking process within the industrial research laboratory is the centralized review and comparison of basic and applied research activities in different areas. Thus, the various areas of a given industrial laboratory's basic research program ideally compete for shares of what in many cases is a fixed total budget for basic research. Rather than being determined by historical tradition, basic research investment is at least moderately responsive to the shifting merits of different scientific fields and to changing corporate requirements. No such competition among scientific research areas takes place in the formulation of the Federal basic research budget, which amounts to more than $8 billion in the President's proposed fiscal 1986 budget, in large part because of the fragmented nature of the process through which this budget is determined. While there is a formal across-the-board review of civilian R&D within the Executive branch budgetary process, the larger generic issues of the allocation of basic or applied research monies across different scientific disciplines typically receive little attention. At best, agency R&D budgets are compared. The White House Office of Science and Technology Policy undertook such a central review of the gamut of Federal civilian basic research priorities in 1982. Such a review should be undertaken on an annual, or at least biannual, basis, with a larger professional staff and closer cooperation with the OMB review cycle. Any such review also should include basic research funding within the Department of Defense, which now accounts for more than 12% of total Federal basic research funding and seems likely to increase its share.

The fragmentation of this resource allocation process is, of course, much more severe on Capitol Hill. Such fragmentation, while useful in protecting some areas of basic research from the chill winds of budgetary retrenchment, also has the effect of conceding the initiative in any such review to the Executive branch. A comprehensive Congressional review of Federal basic research activities in civilian and defense agencies, undertaken on a regular basis, would greatly enhance the effectiveness and coherence of Federal science policy. One excellent venue for such a review is the Budget Committees within the House and

Senate, perhaps operating through a task force or special subcommittee. Alternatively, this review could be undertaken by the Office of Technology Assessment, with the aid of such outside bodies as the National Academy of Sciences or the National Academy of Engineering.

While the process of review and interagency competition for basic research funds might be aided by the formation of a Department of Science and Technology, this step seems unnecessary. Indeed, nothing in the history of previous Executive reorganizations leads one to suspect that such a step, in and of itself, would support a more effective process of comparison and evaluation among competing areas of scientific research. Moreover, the preservation of a relatively decentralized and pluralistic structure for the management of basic research seems desirable, and is not threatened by the suggestion that the budgetary review of these agencies take into account more explicitly the aggregate basic/applied breakdown and its allocation across different areas of scientific activity.

Another key point of contrast in the management of basic research within the Federal and industrial sectors is the importance of strong links of communication, personnel, and funding between basic and applied research activities. The most successful industrial performers of basic research, such as Bell Telephone Laboratories prior to 1984, are organized so as to maximize the strength and number of such links, through, for example, the adroit interposition of geographic bonds where organizational barriers existed.[4] Thus, the organizationally separate operations of research (which at BTL largely consisted of basic and fundamental research) and development were co-located in major laboratory installations in New Jersey and elsewhere. Similarly, the organizationally separate operations of manufacturing and development (the former being carried out by Western Electric, the latter by Bell Labs) were joined by the presence of Branch Laboratories of Bell Labs located at major Western Electric manufacturing installations.

The importance of these linkages stems from the character of the innovation process; rather than consisting simply of a unidirectional application of basic scientific findings through the applied research and development phases, innovation is a more complex, iterative process, in which the basic research agenda in many cases is informed and enriched by discoveries and results from the applied and development phases of the production of a given innovation.[5] This interactive character of innovation processes means that organizational structures that are able to support such interactions are likely to yield a higher return on the basic research investment.

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[4] An interesting discussion of this principle is found in J.A. Morton, "The Innovation Process in the Bell System," Stanford Electronics Laboratories, November, 1965. Morton was the manager in charge of Bell Labs' development of the transistor during the 1950s.

The implications for Federal science policy of this argument are straightforward, and are illustrated by the history of some of the most successful Federal R&D agencies. The effort to precisely define and differentiate "basic" research from "fundamental applied" research, the former being supported by the Federal funds, and the latter pursued largely by private enterprise, is both hopeless and inimical to the effectiveness of the Federal research investment. Rather than attempting to sever such links, Federal R&D programs should seek to sustain the interaction between basic and applied research activities. Indeed, the National Aeronautics and Space Administration's aeronautics R&T program, which has aided substantially in the development of the industry (commercial aircraft and engines) responsible for the largest single share of U.S. manufactured exports, is noteworthy for its support of both basic and fundamental applied research in the so-called "grey area" between basic research and commercial application. Moreover, this role of NASA, one that seemingly exceeds the self-denying ordinance of the Office of Management and Budget, was endorsed in a recent study by the White House Office of Science and Technology Policy.[6] The NASA model, in which government and industry work together closely on a research agenda that spans not only basic but some applied and fundamental development work, merits wider application. The Center for Advanced Materials Research at the Lawrence Berkeley Laboratory is another example of the potential for a more flexible, interactive structure for Federal support of basic research.

This recommendation does not require substantial funding of purely technological and engineering research alone, as was proposed in the Advanced Technology Foundation bill (H.R. 4361) considered in the previous Congress. Instead, I suggest that in areas identified as yielding a high payoff for basic research investment by the Federal government, the decision be made to support on a selective basis within the same facilities both basic and fundamental applied research. This could be done through a sliding scale of matching Federal grants to industrial or university-industry cooperative laboratories, similar to the mechanism employed by the Japanese Ministry of International Trade and Industry in supporting research and development in industries such as commercial aircraft and computers.[7] Among Federal agencies other than NASA, the National Bureau of Standards and the vast array of national laboratories are excellent vehicles for such a modified program of research support.

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[5] See N. Rosenberg, "How Exogenous is Science?" in *idem.*, *Inside the Black Box: Technology in Economics* (Cambridge University Press, 1982).

[6] *Aeronautical Research and Technology*, Executive Office of the President, 1982.

The existing theoretical apparatus of economics is a weak reed for the formulation of science policy. In order to utilize the important empirical findings of economists as a guide to such policy formulation, we require a more detailed understanding of the complex process of decisionmaking in industrial research, as well as the ways in which the organization of R&D influences the success and character of the innovation process. This more detailed understanding requires a sustained research and data collection effort, one that is currently in jeopardy. Nonetheless, consideration of a few generic principles employed in the organization and management of industrial research suggests some important ways in which current federal policy for the support of R&D could be changed and improved. Specifically, a more comprehensive procedure for the review and comparison of the numerous different areas of scientific research receiving Federal basic research funding in both the Executive and Congressional branches would increase the increase the economic returns to the Federal basic research investment, while supporting greater accountability and logic in research priorities. In addition, the distinction between basic and fundamental applied research should not be applied so as to impede the important interaction between these processes, and thereby undermine the effectiveness of Federal R&D programs.

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[7] See D.C. Mowery and N. Rosenberg, *The Japanese Commercial Aircraft Industry Since 1945: Government Policy, Technical Development, and Industrial Structure* (Stanford University N.E. Asia-U.S. Forum on International Policy, 1985).

Mr. FUQUA. Before I forget, we had Dr. Edwin Mansfield, department of economics at the University of Pennsylvania, that was to be here and could not make it this morning, and I would like to insert his statement into the record at this point, without objection. (See Appendix 1 for Dr. Mansfield's prepared statement.)

DISCUSSION

Mr. Lujan.

Mr. LUJAN. Dr. Griliches, did you have an opportunity in your research to do it by industries like, you know, steel and automobile on the one side and the communications industry, the computer industry on the other side, by industry?

Dr. GRILICHES. Yes and no.

Mr. LUJAN. My question really is the general feeling, I would think, that those industries that have moved ahead like the computer industry and satellite industry and those put more money into research and thereby become the leaders, and steel and automobiles and railroads did not invest the proper percentage in research, and therefore, have fallen behind. Can that general conclusion be drawn?

Dr. GRILICHES. Well, you are now asking me—I think the facts of the general correlation are in the direction that you are saying. I would be a little bit worried about making a very strong causality connection, particularly for things like steel or automobiles, and I don't think that it was the case, particularly in automobiles; that, in fact, reasonable amounts of research money were spent in automobiles, and we can argue whether it was spent correctly.

So, I think, that these industries went through a very bad time which I think was not related or not directly related to the research output at that point in time, and given that they have fallen on bad times, some of them, they have also spent less money on research. So there are some aspects of reverse causality in those numbers.

But I have been able in my study to separate it into about 19 industries, and by and large, the conclusion that I found about the relationship between R&D and productivity holds up for most of the industries examined separately.

So the thing is there, and it is not just peculiarly that it is for one industry or another, even though it is clear that some of the effects are stronger in some industries than others, though in some of the cases it is sort of not obvious why.

The other problem is that even though it looks as if we have lots of data—you go down to have 900 companies and maybe 15 years—at the individual level, there was a tremendous amount of different experience. Some companies spend a lot of money and get unlucky by being at the wrong business at the wrong time, and some companies don't spend much money but are able to free ride on somebody else sort of when the wave hits them.

What I am telling you about is sort of a general tendency, but when you look at the data, the other thing that one is impressed with is how variable is, in fact, the individual experience.

Mr. LUJAN. Thank you.

Mr. FUQUA. Thank you, Mr. Lujan.

One of the questions that we get and I guess we are all concerned about—it is probably a rather broad subject—but how much is enough research, and how does industry establish research levels, both dollarwise as well as the quantity? Are there traditional levels of support that are rough guidelines? I think you mentioned, back in the early 1960's and early 1970's, the decline and then upturn. Should it be based on GNP, or should it be based on a dollar figure that you are always putting a little more each year than you did the previous year? How do we address that? I ask that to both of you because I think you have a very excellent background to enlighten us on that.

Dr. GRILICHES. I don't know that there is a magic answer to this.

Mr. FUQUA. We have been looking for it.

Dr. GRILICHES. Just because you spend whatever, 3 percent of sales on it, there is no argument to do it next year again if it is money down the drain.

So the question is, there has got to be a feeling, there has got to be a scientific base in an area, there has got to be something that you actually can see your way into there potentially being something useful out there.

Now, when you see companies actually spending this certain amount over a certain period, you assume that in fact they are drilling in some technological oil fields which are not unreasonable, and then you worry if their levels are declining, and then you ask yourself, are they declining because there is less out there, or are they declining for other reasons?

I think one of the major questions on which people are divided is sort of whether there is a sense in which, if there are diminishing returns, if you have searched all of the chemical compounds and you have now researched them first sort of by hand and now you are doing it by computers, and the next compound you can find costs you seven times more to search than the one before, then maybe that line of work is becoming exhausted, and you sort of should not be spending that much, or the amount that you are spending, you are actually getting less for it.

My reading of the evidence—and there is very little relevant evidence on the topic—is that we are not, in industry, in a situation in which there is a decline of opportunities, so that the argument that you should not be spending more because it is not there, I don't think the scientists and engineers would support that.

There has been a real rise in the cost of doing research, I think, which is underestimated by the standard kinds of deflators.

Mr. FUQUA. But you have artificial things sometimes that make it appear you are doing more for research. For instance, as a result of Sputnik in 1957, then we became involved in the early 1960's in the Apollo program.

Dr. GRILICHES. Right.

Mr. FUQUA. NASA did not even exist. It was a small agency dealing with aeronautics prior to that time. But there was a big thrust, a big thrust in education, in science education. The NSF budget started increasing. So maybe that gave a false bubble in the chart, and then as that started declining, then in the early 1970's—1973, 1974—we had an energy crisis and everybody said that we have to solve our energy situation very rapidly. There was a big thrust to put research dollars into particularly fossil fuel and increase the amounts for fusion and a lot of programs of that type which have put another bubble in that that was really not a constant program of research but a response——

Dr. **Griliches**. That is right.

Mr. **Fuqua** [continuing]. And, I might say, a political response to certain initiatives or issues that develop that the American people and the Congress and the Government agencies and so forth, in responding to that, made these pushes. I am not sure that that does not distort the real meaning of how much we are putting into that.

Dr. **Griliches**. Well, it clearly does. There is a problem of these cycles, and I think it not only distorts the meaning; it also distorts the enterprise, because we have boom and bust, we have put on things; we have tried to retrain some people for something, and then we don't have the jobs for them, and then we want suddenly people for something, and they are nowhere to be found.

There is another number in there which I sort of came across, which sort of struck me, that in the whole Federal budget, if you think about categories, there is a category of support of general science, which is the basis, you would think, of all of it, and that is only 4 percent. Only 4 percent of total Federal R&D goes for support of general science.

It seems to me that one of the things that needs to be done—it is hard to say whether it should be 10 percent or 5 percent or 17 percent. But one of the things that I think is clear is that there ought to be a piece of support for general science that is relatively stable and does not swing so that some day we get excited about cancer and the biological budgets get raised a great deal, and then we have a crunch with the deficit, and you start turning them off, and so you sort of put things on and then you take them off, and I think, as a result, there is quite a bit of waste and also inefficiencies in the system.

I think if you think about investment in R&D, as a kind of investment, an investment in the future of the growth of the economy, we cannot get, in the long run, productivity growth without improvements in the technology, because, in the long run, you can just sort of get so much machinery, and the people will expand and the machinery will depreciate. It is not a sustainable rate of growth. The only rate of growth that you can get sustainable is if we are actually managing to improve the technologies with which we are converting resources into useful things.

If you believe in diminishing returns, then in fact it would be clear that you would have to expand that activity over time. At a minimum, you need to keep it constant, I would think. If you look at the numbers by any criteria since the—now, the 1960's may be a bubble, but we have been drifting downward relative to the scale of the economy, relative to the past, relative to the foreign activities.

We have barely kept our setup going in absolute levels. We have levels in the research establishments today which are not significantly different from what we had 15 years ago, while the rest of the world has moved, and the economy even in this country has moved.

My feeling is that that is probably too little. I am not arguing that—we could not double it tomorrow, but we might think of doubling it over the next 10, 20 years.

Dr. **Mowery**. I think, though, that in thinking about the sort of magic numbers, that thinking in very aggregate terms can be somewhat deceptive, I think; that looking at shares of GNP, comparing the United States to major industrial competitors, shares of GNP devoted to total research do not match productivity performances, do not correlate at all.

You have to look beneath the aggregate numbers to the public-private mix, the military-civilian mix, I would say, and these are really the critical things, and these intersectoral data really are where we are weakest, I think, in our understanding. I certainly hope that over the next 18 months, we will also be able to illuminate our understanding.

Mr. **Fuqua**. Let me just ask you briefly, because we are running out of time, in 1945 when Vannevar Bush did the report, "Science, The Endless Frontier," one of the points he made was that there was an appropriate role for Government support; that Government should not be too big because it would stifle the incentive of industry to support research. How do you see that in light of today's R&D world that we live in? Is there an appropriate level of Government support, and through maybe tax incentives or other means that industry should support, that we do not push them out, in 25 words or less?

Dr. **Mowery**. I think the available evidence suggests that Government—certainly the current level of Government support of R&D within industry does not seem to be—I mean, there are conflicting findings, but the preponderance of evidence suggests that Government support of R&D within industry does not displace industry expenditures.

I think that certainly the experience of some of the Government interventions far down the continuum toward commercialization—SST, energy demonstration projects—perhaps suggests that there is some middle ground past which they are not well advised to go, but I certainly have argued, and I think that it is sort of a self-denying ordinance that only basic and, however that is defined, only areas in which the private sector for some reason cannot invest are the appropriate areas.

That is almost impossible to find, and I think it really does impoverish to some extent and reduce the rate of return to the existing Government—particularly, basic R&D does—and I think the NASA case is really a good one of an agency that did not restrict itself solely to basic but went down-line and reaped very substantial returns for itself.

Dr. **Griliches**. I am not disagreeing, except that I would like to emphasize the importance of support of general science based in universities and in institutes and Government institutes.

I have no particular brief for one form or another. I think, other things equal, I would be for doing something, and I don't mind if it is done by the Government in NBS or in NIH or it is done in the universities. Rather than arguing about territory, it is arguing about what needs to be done which is more important.

Mr. **Fuqua**. Well, thank you both very much. I wish we had more time. We are kind of like television—we kind of have to have a commercial break—and we have several other witnesses or participants this morning. But I want to thank you both very much for a very enlightening presentation.

Dr. **Mowery**. Thank you.

Dr. **Griliches**. Thank you.

Mr. **Fuqua**. Our next witness will be Dr. Clark Wescoe, chairman of Sterling Drug Co., and a member of the board of the Pharmaceutical Manufacturers Association. I see he is accompanied by the chief honcho of that group back in the back. We are glad to have you, Mr. Mossinghof.

Mr. **Mossinghof**. Thank you, Mr. Chairman.

Dr. **Wescoe**. Would you rather he stayed behind me, or would you like to have him beside me, Mr. Chairman?

Mr. **Fuqua**. Well, if you know him like I do, you don't ever want him behind you. [Laughter.]

I say that in jest.

Dr. **Wescoe**. I would be pleased to have him beside me if he would like to.

Mr. **Fuqua**. Mr. Mossinghof has been before us many, many times over a long number of years, and we have great regard for him.

STATEMENT OF DR. W. CLARKE WESCOE, CHAIRMAN OF THE BOARD, STERLING DRUG, INC., ON BEHALF OF THE PHARMACEUTICAL MANUFACTURERS ASSOCIATION, ACCOMPANIED BY GERALD J. MOSSINGHOF, PHARMACEUTICAL MANUFACTURERS ASSOCIATION

Dr. **Wescoe**. Well, you know my name, Mr. Chairman, and I am the chairman of the board of Sterling Drug, Inc., but this morning I represent the Pharmaceutical Manufacturers Association.

I suspect that I was asked by the association to be its representative this morning because immediately prior to my coming to industry, I had served as dean of the medical school of the University of Kansas for 8 years and then had served 9 years as chancellor of that university. I have had the opportunity, therefore, over a period of more than 25 years, to see the industry/academic interactions from both sides of the fence.

PMA thanks you, Mr. Chairman, for giving us the opportunity to testify. Hopefully, we will be able to provide some facts and figures that will be of assistance in your deliberations. You were kind to send me a summary of your objectives and a copy of the agenda. In that agenda you highlighted several questions for me. I would like to address myself specifically to those questions and add a few thoughts on pharmaceutical research and development, particularly related to interactions between the industry and Government and industry and the academic world.

By way of history, in 1964 our pharmaceutical firms represented in the association invested $313 million for all research and development. In 1984, the year just closed, for research, both basic and applied, the pharmaceutical industry invested $3.5 billion. That is, over that period of time, 17 years, an increase 10-fold in amount.

This year, the figure is expected to reach about $4 billion. Those figures, incidentally, represent, over the years, approximately 11 to 13 percent of the sales revenues of those companies. Our investment in research is high because research is the lifeblood of the industry.

We feel that there is still much to discover from the standpoint of providing new medicines for man. We agree with the statement written by Emerson some 100 years ago who said there was an evil thought abroad that the world had been finished at some time in the past.

Those figures that I gave you—$3.5 billion last year, approximately $4 billion this year—represent worldwide investment. But as a rule of thumb, approximately 80 to 82 percent of those funds are expended in the United States. Of that total, less than one-quarter of 1 percent comes from Federal sources. Our industry, therefore, is perhaps unique—certainly it is unusual—in that its research is funded almost entirely from its own resources, and at an annual rate of increase in the last 5 years of some 15 to 20 percent.

You asked about investment in basic research, and I have to tell you that PMA does not routinely maintain statistics on an ongoing basis that break down figures into those related to what some would call basic research and what others call applied research. As our professorial friends indicated earlier this morning, the treatment of those figures is in fact elusive. The definition of basic research varies from people to people. One could describe, for instance, in our industry all of the research related to pharmaceutical chemistry, the production of new compounds, the discovery of new chemical entities, and new processes to discover those new chemical entities as basic research. Similarly, one could take all of the pharmacology that is done within our research laboratories to elucidate the mechanism of action of new medicines as purely basic research. But other definitions are possible, and I just cannot give you, on behalf of the association, actual figures in that regard.

Pharmaceutical companies expend, on the average, 80 percent of their research allocations in their own laboratories, in-house in the vernacular. The other 20 percent we expend—and that is primarily for clinical investigation—the last part of pharmaceutical research is spent almost entirely through universities, university-related hospitals, and under the supervision of university faculty members. There is, therefore, a strong interaction between the industry and our basic educational institutions.

Once more in that regard—and I think I must mention it—our research program is unique in that its final phase is carried out, to be sure, under our supervision, but it is carried out by the hands of others. We cannot do the ultimate step in our own research because it rests in the investigation of medicines in man, and that must be carried out by others.

Before World War II, as you and I know, universities and industry shared many productive research arrangements. After the war, there were greater Federal investments in science and in research, and those links between industry and the academic world, I think, really weakened. However, over the last 10 years, agreements between our industry and universities have been growing in number, and I believe a mutual respect has been regained and new respect has been engendered on both sides.

Although these agreements provide much-needed funds to the academic world, I must point out, as I have in the past to university officials, they can in no way take the place of diminishing Federal support. Our pockets just are not deep enough to accomplish the fulfilling of those requests.

Now, our agreements between industry and the academic world take many forms. We make capital contributions for buildings, for equipment, and I am reminded constantly now, Mr. Chairman, that one of the great requirements from the standpoint of the universities is their requirement for sophisticated instrumentation and up-to-date, state-of-the-art equipment so that their educational programs can meet the demands of their students who will be going out and using those kinds of instruments in the future. We provide as well on-the-job training for students in specialized fields and participation, in some locations in the industry, with universities in training graduate students by providing for sophisticated laboratories to them.

We do, of course, have our contracts for clinical trials, which I have mentioned. We have consultancies with university professors. We underwrite specific research projects of a basic nature. We have endowed professorships and fellowships in the university world, and in some instances, and very recently, some of our companies have provided substantial endowments for individual departments.

Beyond those individual agreements, I should point out that industry, through the Pharmaceutical Manufacturers Association Foundation, supports now and has supported over a good many years educational training and research in universities. Since 1967, through that foundation, a total of 586 individuals in nine university research centers have been supported by the foundation or through the foundation in basic research and research training. I believe that improved working relationships between industry and the academic world will strengthen immeasurably our research and development activity in this country. There really is little reason for there to be distrust between the two sectors, and I think there is very little that exists today.

Each of those sectors has the same approach to science, and each has the same accountability. Universities have their accountability to their peers, primarily, and industry has its responsibility and accountability not only to its peers but to the public, and to the public that comes through the Food, Drug and Cosmetic Act which, as we all know, prescribes criminal penalties for lack of accountability. That is quite different from the university world.

I think I should say here, Mr. Chairman, that when there was a great deal of flurry about so-called good laboratory practices in research laboratories, one of the agencies surveyed four kinds of laboratories, those in the pharmaceutical industry, those in free-standing research institutes, those in universities, and those that were run by the Government itself. Not surprisingly to us, but I think to that Federal agency, the results came out that the most accountable research and the best records were kept by the industry; the second, by the free-standing research institutes; the third, by universities; and the last, by the Federal laboratories themselves.

The sorts of Federal policies we support relative to research are not necessarily economic incentives per se. We do very much support and find very helpful the research and development tax credit which you have mentioned already this morning with those other witnesses. We believe that is essential from the standpoint of the fact that our financial resources are, after all, limited.

The Federal policies critical to maintaining a worldwide competitive edge, particularly in our own industry, include several other things as well; that is, the continuing Federal support of basic research, which is the frontier; the Federal support of research training; relaxation relative to joint ventures between companies in our industry. We have avoided those joint ventures in the past, sir, because of the possible violation of antitrust legislation. We need intellectual property protection. We need early Food and Drug Administration approval for the new drugs that we develop. And we must take a look, I think, at health care financing policies as they do relate to research in our industry. In respect of that latter, we recognize as well as everyone else the need to contain costs in the medical care sector in this country, but we do have objections to those things that are apparently easy but shortsighted ways chosen to accomplish that.

There are restrictive formularies, for instance, in hospitals and in State government and in Federal Government that oppose and delay the addition of new medicines, and that ultimately reduces the funds that are available to industry for research. Restricted formularies are, I guess, the hope of those who believe that there will be no new discoveries, who believe that there is a small list of essential drugs to which no new ones will have to be added and which will take care of everybody for years to come. Limited access to drugs is in no way cost effective, and I believe you have the record from the standpoint of the cost effectiveness of medicines in the health care sector. They are the most cost-effective form of medical care that is available today. We believe, therefore, that health care financing policies need to be reviewed with the R&D incentive perspective in mind.

You asked me as well, sir, to respond to the matter of employment. We do not keep, in the industry, statistics relating to graduates from U.S. institutions and those of foreign-trained personnel. I believe that same fact is true of other industries as well. We do have the overall data relative to our employment. The latest figures we have from the industry in total give an employment of 16,300 scientific and professional personnel, 6,200 technical personnel, and 6,600 supporting staff.

As for the needs of the future, I think no one really can determine what our future needs for personnel will be and in what category of personnel those needs might fall. The Bureau of Labor Statistics—and those data, I believe, are still unpublished—does, however, estimate that an additional 75,000 to 80,000 scientists and engineers will be required by our industry 10 years hence in 1995. Some of us saw this morning the article in the *New York Times* relating to the requirements for chemical engineers. I will leave this with you.

The statement is made here by Dr. Arthur Humphrey, professor of biochemical engineering at Lehigh University, that we are now educating only one-third of the chemical engineers that will be required in the near future for American industry and for the continuing teaching of chemical engineering.

People who are well educated and well trained are the key to future competitiveness, not only for our industry but for our country as well, and all of us in the private and the public sector are going to have to increase our contributions to educational institutions in a meaningful way.

Relative to publications and what they might mean, Mr. Chairman, there is a mistaken impression held by many that industry scientists do not contribute to the advancement of science by publishing in the open literature. I do not think that is true. Assessing rates of publication is difficult and, to me, not only as one in industry now but in the academic world as well in the past, of very questionable value. All scientists, industry, and academic, thrive on presenting to their peers the results of their work. That is, after all, the only way in which they can let their colleagues know what they are doing and what they have accomplished.

Industry scientists are not under pressure to publish; university professors are. And those pressures sometimes, I believe, lead to the publication of marginal articles. Weight of publication, therefore, is no accurate assessment of worth in one's contribution to science. That is my opinion.

Now, it should be mentioned as well that industry does spawn a great deal of literature in the clinical field, in particular in clinical pharmacology, because the results of its research are really written up by others who are, after all, in the academic world.

Now, let me finally—and I did not ask Mr. Mossinghof about this, or the PMA, either—let me finally comment on a matter that I think, personally, is something of great importance to us from a standpoint of research in this country and the Federal policy.

Our conflict-of-interest statutes are, I believe, the most repressive of any nation's. We tend to carry conflict of interest in this country to ridiculous extremes, in my opinion. It must seem apparent to all that industry seeks the best minds for its consultancies. When we have a new cardiac drug, we don't go for the second-level or third-level cardiologist; we go for those who are at the top. The consultants it chooses are often considered tainted by that consultancy or by any industry connection, and tainted to such an extent that they might be excluded from governmental advisory groups in the future in their own field of expertise.

That fact leads to several deleterious conclusions. It leads to the fact that advisory groups may not always have the best minds giving advice, because those people have been excluded; and, additionally, that those advisory groups may show an anti-industry bias because they have not been asked by industry to be consultants. The makeup of Federal panels, I believe, should be governed by the need to bring the best minds together regardless of the outside arrangements they have, so long as those outside arrangements are clearly identified and well known to everyone. I hate to say this, but science and scientists are not without prejudice. I say that because I was one, myself, at one time.

Our English colleagues, incidentally, and their government handle these matters of conflict of interest, I think, in a much more seemly way than we do.

Now, those last comments were all of my own, and Jerry does not have to take any responsibility for those. I think, on the others, he will be with me.

And now I would be pleased to respond to any of your questions, sir.

[The prepared statement of Dr. Wescoe follows:]

SCIENCE POLICY AND THE PHARMACEUTICAL INDUSTRY

TESTIMONY BEFORE THE
TASK FORCE ON SCIENCE POLICY
APRIL 24, 1985

W. CLARKE WESCOE, M.D.
CHAIRMAN OF THE BOARD, STERLING DRUG INC.
ON BEHALF OF
PHARMACEUTICAL MANUFACTURERS ASSOCIATION

I am W. Clarke Wescoe, Chairman of the Board of Sterling Drug Inc., representing this morning the Pharmaceutical Manufacturers Association (PMA). I was asked by the Association to represent it because, immediately prior to my coming to Sterling, I had served 8 years as Dean of the Medical School of the University of Kansas followed by 9 years as Chancellor of that university. I have, therefore, seen industry/academic interactions from both sides.

Thank you, Mr. Chairman, for giving PMA the opportunity to testify before this Task Force. Hopefully, we will be able to provide you with some facts and figures to assist in your deliberations. You were kind to send me a summary of your objectives and a copy of your Agenda. You highlighted several questions for me; I will attempt to answer each of those questions and add a few thoughts on pharmaceutical research and development particularly related to interactions with government and the academic world.

II.C.1. In 1964 our pharmaceutical firms invested $313 million for all research and development. In 1984, for research both basic and applied, the pharmaceutical industry invested $3.5 billion; this year the figure is expected to reach about $4 billion. Those figures represent worldwide investment; as a rule of thumb, 80-82 percent of those funds are expended in the United States. Of the total, less than 1/4 of 1 percent comes from Federal sources. Our industry is, perhaps, unique in that its research is funded almost entirely from its own resources and at annual rates of increase in the last five years of 15 to 20 percent.

PMA does not maintain statistics on an ongoing basis breaking down figures into those related to "basic" and "applied" research. Treatment of those figures is, in fact, elusive. One could describe all research related to pharmaceutical chemistry, analytical chemistry and pharmacology as basic.

PHARMACEUTICAL COMPANIES EXPEND, ON THE AVERAGE, 80 PERCENT OF THEIR RESEARCH ALLOCATIONS IN THEIR OWN LABORATORIES. THE OTHER 20 PERCENT, PRIMARILY FOR CLINICAL INVESTIGATION, IS SPENT ALMOST ENTIRELY THROUGH UNIVERSITIES, UNIVERSITY-RELATED HOSPITALS AND UNIVERSITY FACULTY MEMBERS. ONCE MORE, OUR RESEARCH PROGRAM IS UNIQUE, IN THAT ITS FINAL STAGES ARE PURSUED BY OTHER PERSONNEL UNDER OUR SUPERVISION (AND THAT, BY LAW).

BEFORE WORLD WAR II, UNIVERSITIES AND INDUSTRY SHARED MANY PRODUCTIVE RELATIONSHIPS. WITH GREATER FEDERAL INVESTMENTS THEREAFTER, THE LINKS WEAKENED. HOWEVER, OVER THE LAST 10 YEARS AGREEMENTS HAVE BEEN GROWING IN NUMBER AND, I BELIEVE, MUTUAL RESPECT HAS BEEN ENGENDERED. ALTHOUGH THESE AGREEMENTS PROVIDE MUCH NEEDED FUNDS TO ACADEMIA, THEY CAN, IN NO WAY, TAKE THE PLACE OF DIMINISHING FEDERAL SUPPORT.

AGREEMENTS BETWEEN OUR INDUSTRY AND ACADEMIA TAKE MANY FORMS:

- CAPITAL CONTRIBUTIONS
- ON-THE-JOB TRAINING FOR STUDENTS
- CONTRACTS FOR CLINICAL TRIALS
- CONSULTANCIES
- SPECIFIC RESEARCH PROJECTS OF A BASIC NATURE
- ENDOWMENTS FOR PROFESSORSHIPS AND FELLOWSHIPS
- ENDOWMENTS FOR DEPARTMENTS.

BEYOND THESE INDIVIDUAL AGREEMENTS, THE INDUSTRY, THROUGH THE PMA FOUNDATION, SUPPORTS EDUCATIONAL TRAINING AND UNIVERSITY RESEARCH. SINCE 1967, A TOTAL OF 586 INDIVIDUALS AND 9 UNIVERSITY RESEARCH CENTERS HAVE BEEN SUPPORTED THROUGH THE FOUNDATION IN BASIC RESEARCH AND RESEARCH TRAINING.

IMPROVED WORKING RELATIONSHIPS BETWEEN THE TWO SECTORS WILL STRENGTHEN IMMEASURABLY R&D IN THIS COUNTRY. THERE IS LITTLE REASON FOR THERE TO BE DISTRUST BETWEEN THE TWO SECTORS -- EACH HAS THE SAME APPROACH TO SCIENCE AND EACH HAS THE SAME ACCOUNTABILITY — UNIVERSITIES TO THEIR peers and industry to its peers and the public (through the FD&C Act which prescribes criminal penalties for lack of accountability).

II.C.3 The sort of Federal policies we support are not necessarily only economic incentives, such as the R&D tax credit which we believe essential in the light of limited financial resources. Federal policies critical to maintaining a worldwide competitive edge include, as well:

- Federal support of basic research (the frontier)
- Federal support of research training
- Relaxed joint-venture regulations (antitrust)
- Intellectual property protection
- Earlier FDA approval for new drugs
- Health-care financing policies.

In respect of the latter, we recognize the need to contain costs but we do object to apparently easy but shortsighted ways sometimes chosen to accomplish that. Restrictive formularies that oppose the addition of new medicines ultimately reduce the funds available to industry for research. Further, limited access to drugs is not cost-effective. Medicines are the most cost-effective form of medical care available today. Health care financing policies need to be reviewed with the R&D incentive perspective in mind.

II.C.4 The industry does not keep employment figures for U.S. graduates and foreign-trained personnel. I believe the same is true for other industries. We do have overall data. Our latest figures (1982) indicated employment of 16,300 scientific and professional personnel, 6,200 technical personnel and 6,600 supporting staff.

No one can determine what our future demands for personnel, and of what nature, might be. The Bureau of Labor Statistics (unpublished data), however, estimates that an additional 75 to 80,000 scientists and engineers will be required by our industry in 1995.

Specifically, specialists in the field of pharmaceutics are already in short supply. The Association is working with our colleges of pharmacy to solve this problem.

People, well educated, well trained, are the key to future competitiveness. All of us, the private and public sectors, will have to support our educational institutions in a meaningful way.

II.C.6 There is a mistaken impression held by many that industry scientists do not contribute to the advancement of science by publishing in the open literature. Assessing "rates of publication" is difficult and, to me, of questionable value. All scientists thrive on presenting to their peers the results of their work. Industry scientists are not under pressure to publish; university professors are -- and those pressures sometimes lead to the publication of marginal articles. Weight of publications is no accurate assessment of worth.

Let me, finally, comment on a matter that I consider of great relevance to the furtherance of research. Our conflict-of-interest statutes are, I believe, the most repressive of any nation's. We tend to carry them to ridiculous extremes. Industry seeks the best minds for its consultancies. The consultants it chooses are often considered "tainted" by an industry connection -- tainted to such an extent that they may be excluded from governmental advisory groups. That fact leads to several deleterious conclusions: advisory groups may not always have the best minds giving advice and, additionally, may show an anti-industry bias because they have not been asked to be consultants. The makeup of Federal panels should be governed by the need to bring the best minds together regardless of outside arrangements (so long as those are clearly identified). Science and scientists are not without prejudice. Our English colleagues handle these matters much better than do we.

Mr. Chairman, I would be pleased to respond to questions.

DISCUSSION

Mr. **Fuqua**. Thank you very much.

You mentioned several factors including the latter about the Federal policy not directly related to science. Some of those—you mentioned intellectual property, antitrust, taxation, immigration—well, you didn't mention those, but those are some of those that can inhibit investments in the conduct of research, and you did touch—and maybe there are some others—on unintended barriers to private sector research that Congress consider changing.

Now, I am really talking about research, not in the regulatory sense of the word. You alluded to a few, but are there any others that you consider as barriers that Government has erected?

Dr. **Wescoe**. Well, I cannot think of any, really, offhand that I have not mentioned in my presentation. I think I mentioned at least the crucial ones. I cannot conceive, I cannot think of any other barriers at the moment that I would like to comment upon.

Mr. **Fuqua**. You were here a few minutes ago when I asked the question that Vannevar Bush had indicated in his report, that Government support for basic research was essential, but that there was a point that it could impede private support. As a former scientist, I guess still a scientist, and on the other side of the fence in industry today, how do you view that in light of today's situation?

Dr. **Wescoe**. Well, I guess, rather cryptically, I did comment upon that in what I said earlier. I think Dr. Bush was correct. I think there has to be a balance achieved.

I suspect what he had in mind was that with a great flow of dollars from the Federal Government into the research arena, the people in the private sector might think that everything was being done that should be done and therefore close their pockets from the standpoint of providing to others the funds for research, such as the universities.

As a matter of fact, when I was in the university world, I used to receive that comment when, as every other university president, I went, hat in hand, to alumni and to corporations seeking funds. They said, "The Federal Government is providing it."

I alluded to it cryptically by pointing out now that there was no way in which the private sector, and industry in particular, can pick up the reduction in support that has occurred, that has been felt by the university world. We can, to be sure, even if we doubled what we do today, pick up just a minuscule amount of what the Government has done. I don't think the impression should ever be given that the Government is the be-all and the end-all to the support of research.

Mr. **Fuqua**. Mr. Ritter.

Mr. **Ritter**. Thank you, Mr. Chairman.

Dr. **Wescoe**. Why, good morning. How are you?

Mr. **Ritter**. Good morning. Dr. Wescoe is my constituent, and I regret coming a little late. We had one of those interesting Republican conferences. I am sure you are familiar with the kind of Democratic caucus that is most, quote, interesting, unquote. But I am delighted to be here and to go through some of your testimony.

You talked about conflict-of-interest rules here. Could you compare, in particular, the Japanese situation in terms of the interaction between industry people and Government there, the relationship between industry and Government people there and here?

Dr. Wescoe. I think I probably cannot comment on it any more vividly than to say we all talk about the interaction between Government and industry in Japan as "Japan, Incorporated." They really do not see any conflict of interest in areas where we do.

My feeling about conflict of interest relates to the fact that those who might have connections between industry at the consultant level for having received support for research in the past by industry should not be excluded from Government panels and the like just because they have had that connection. I think the English system is one that really handles the circumstance very, very well. All of the so-called conflicts are put on the table.

You know who I am this morning. Nobody expects me to speak against Sterling Drug. On the other hand, I want you to know that I don't think, because I am the chairman of Sterling Drug, I cannot respond honestly to your questions. As long as you know who I am, then I think we ought to be able to talk together.

Mr. Fuqua. Disclosure.

Dr. Wescoe. Right.

Mr. Ritter. Sometimes I get the feeling in Japan that the relationship between industry and Government is not only intimate; it is indistinguishable, and it is hard to tell, in particular in terms of the Ministry of International Trade and Industry, it is very hard to tell who is with the Government, who is with industry, who is with the trade association, and where the salaries are coming from. They don't seem to get hung up on that kind of adversarial relationship.

As we look to our future, we are either going to have this kind of teamwork, because in that teamwork is synergism, and in that synergism is just higher productivity and higher creativity, we are either going to have it or we are going to lose, one by one, those areas of competition where the Japanese have decided to go full-bore and play their team game against us.

I have another question, and that is, how does Government's regulatory policy, particularly the regulatory policy that seems to be accelerating here in the Congress vis-a-vis all things chemical, how does that impact on your industrial competitiveness future, your R&D plans and what you see happening?

Dr. Wescoe. Well, it does have an obvious impact upon it. It increases the cost of research without question from the standpoint of the toxicological studies that we must carry out now longer than those that we carried out in the past.

It really makes industry think about the liabilities of the future. That is one of the difficulties in research today. There is no medicine that is safe for everyone. As a matter of fact, the statute may in that regard lead the American public on.

When we say a drug is "safe and effective," we don't mean it is safe for everyone. No drug can be because of the very fact that it is a drug. Similarly, it sometimes is not effective for everyone. Generally safe and effective is what they are.

We are faced with the prospect always of the fact that facts we do not know now or could not determine could lead to liabilities in the future. We do all of the necessary testing that we can and hopefully know all that we can about a compound before it becomes a product. Regulatory procedures are necessary, but from the standpoint of the introduction of new medicines, they do shorten the patent life of medicines. We are required, I think, sometimes to complete investigations not from the standpoint that those investigations are going to add significantly to our knowledge of the new medicine but simply to provide data for the sake of data. I object to that. I think we could streamline some of the regulatory procedures that we have now. All new agency heads always say that is what is going to happen. It is unusual when it does.

Mr. **Ritter**. Does this have particular relevance to, say, our industrial competitiveness in the area of vaccines? It seems that at one point, the United States is performing the basic biomedical research to develop vaccines, and in another stage, when it comes to producing them, we are exporting the production because we are concerned with liability.

Dr. **Wescoe**. My company is not in the vaccine business, and that is probably one of the reasons why it is not. The production of vaccines is a specialty. Everyone knows, just like drugs, that vaccines cannot be safe for everyone. It is not possible for an individual company to speak to the parent of every child who, in a public health measure, is going to be vaccinated about the possible adverse effects or side reactions to those vaccines, and under those circumstances, the companies must withdraw from their production.

We ran into that phenomenal circumstance when we had the swine flu scare several years ago. We know that there was an arrangement between industry and Government at that time relative to the liabilities that would be incurred. I think everyone was astonished at the level of those liabilities. I think there are several billions of dollars' worth of suits still outstanding relating just to that specific episode. There is no way a company can open itself up to that kind of liability in the future, with the determination that if a patient is going to get the vaccine in the light of a public health move, that each patient must be spoken to individually.

Mr. **Ritter**. It is quite possible, therefore, that we could invest vast sums of money in new chemical technologies—and let's face it, drugs are chemicals and chemicals are sometimes drugs; they are really indistinguishable—that over this liability question, we could do some of the finest basic science in the world and not see the jobs and the products here in this country.

Dr. **Wescoe**. That possibility exists.

Mr. **Ritter**. I have just a quickie. How would you stimulate further direct university-industry research, that is, direct without having the proposal process? I think it is becoming very well known within the academic community—that is, the Government grant/contract proposal process—that vast sums of effort and administrative resources and faculty time are being used in the grantsmanship game.

Do you have any ideas as to how to stimulate more direct private sector R&D support for universities? This has a tendency, also, to make the research more focused on products and markets and competitiveness.

Dr. **Wescoe**. I don't think I have any ideas, Don, beyond those that have been propounded by others. I do think we all have to increase our contributions to the university world, and all of us who have worked in it at one time or the other know that unrestricted funds without strict parameters put around them are the most effective funds for the use of universities.

We do, in my own company, provide unrestricted funds to departments of pharmacology for those purposes from time to time, and we have found them very useful. We find the best interaction between our own scientists and those of the university scientists and our own scientists telling us what the requirements are in the university world and what we might be able to do in small or large ways to assist the universities.

Mr. **Ritter**. Mr. Chairman, thank you very much.

Mr. **Fuqua**. Thank you, Mr. Ritter, and thank you, Dr. Wescoe. We appreciate very much your being here today.

Mr. Mossinghof, we are glad to have you here, and I don't think he got you in any trouble. [Laughter.]

Mr. **Mossinghof**. I agree totally.

Mr. **Fuqua**. It has been very helpful.

Dr. **Wescoe**. He is a great chaperon.

Mr. **Fuqua**. Yes, he is. Thank you very much.

Dr. **Wescoe**. Thank you, sir.

Mr. **Fuqua**. Our next person will be representing industrial research management, Dr. Alexander Mac Lachlan, director of the Central Research and Development Department of the E.I. Du Pont de Nemours Co. of Delaware.

Dr. Mac Lachlan, we are very pleased to have you here this morning, and we will be delighted to listen to you.

STATEMENT OF DR. ALEXANDER MAC LACHLAN, DIRECTOR, CENTRAL RESEARCH AND DEVELOPMENT DEPARTMENT, E.I. DU PONT DE NEMOURS AND CO., INC., WILMINGTON, DE

Dr. **Mac Lachlan**. Thank you very much.

I would appreciate it if you would include my remarks in the record.

Mr. **Fuqua**. Yes, we will.

Dr. **Mac Lachlan**. Good morning, Mr. Chairman and members of the Science Policy Task Force.

My name is Alexander Mac Lachlan, and I am director of the Du Pont Company's Central Research and Development Department.

Let me say at the outset that I welcomed your invitation to come here today.

While some of us may differ on style and emphasis, I am sure that we are in general agreement that research is a vital part of American efforts to regain our international competitive edge and to get our trade deficit down from the stratosphere.

In my opening remarks, I want to comment briefly on how Du Pont manages its research and how at least one aspect of that process relates to the overall national support of basic research.

The second area I would like to note is Government policy as it relates to the environment for industrial research.

Let me start this morning by saying that I think America has proven it does well in research. The informal partnership involving Government, the university, and industry is an effective alliance that meets our national needs within the context of the American way of doing things.

While our efforts reinforce and merge with each other, basically, we have discrete roles. Government funds basic research primarily through the university, and the fruits of basic research, in turn, are developed primarily by industry into new products.

Industrial research is what I know best, so let me focus on that. Just as with every phase of industry, research is subject to rigorous budgetary review. At Du Pont, our R&D budget supports 6,000 professionals with $1.2 billion for the current year. The decision and allocation process is complex, as the fundamental shape of the company and its vision of the future is at stake.

Let me give you some feel for this annual process. In one sense, the budget preparation starts when the individual businesses within the company submit their dollar and scientific personnel requests based on their perceived need. These are derived from the missions that they have been assigned. The missions can be growth or they can be cash generation to fuel the growth.

Our executive committee then weighs these requests versus the strategic plan of the company and the overall business environment, both near and long term. Inevitably, at first cut, the budget requests are too great or don't conform to the overall corporate strategy. The process that follows is one of iteration, iteration, and iteration, and not without some pain and possibly mission changes that may lead to decisions to reduce or even divest some businesses.

In the end, the document is part of the master plan for the corporation's future. In Du Pont's case, the budget is a prime vehicle to move our company away from some of its historic businesses into new areas that include specialty chemicals and polymers and new products for agriculture, electronics, and human health care.

We think of our research budget as composed of five parts: basic research, which seeks new knowledge in areas of interest to the company—and, incidentally, that is exactly the same definition as used by the National Science Foundation, and we think everybody ought to use that and at least we would have consistent numbers—amounts to nearly 6 percent; discovery and development, another 40-plus percent—and that is the area that is designed to get us into new businesses or to make dramatic changes in some of our processes; and, finally, support and extension, at a little over 50 percent, to keep the existing businesses healthy. I think you can see we regard science and technology and their practitioners to be our lifeblood.

Consequently, we feel that Federal science policy ought to assign highest priority to support for basic research and science and engineering education. This long-range investment in trained people, knowledge, and new ideas is an essential part of innovation and international competitiveness.

Almost inevitably in this context the question arises of whether industry can or should do more to help basic research at the university. The National Science Foundation estimates about $6.5 billion of basic research is performed in universities, with roughly $280 million being supported by industry. While I will not say that we are at the limit of industry's ability in this area, my personal feeling is that getting much more basic research support for universities via this route is not realistic.

There is no doubt that industry has a role to play in helping the universities. What is not always recognized is that industry already is an important factor on the campus. My own company, for example, will donate some $16 million this year to promote science and engineering education and to support basic research at the university level. That support is in addition to the basic research we do in our own laboratories.

Many other companies have their own programs to assist universities. Included in this area are a number of joint industry-university entrepreneurial partnerships involving scientific research. Ultimately, these may provide an important infusion of new funds into the university-scientific community. But I should point out that this sort of industry investment will flow largely into the newer and more critical areas such as the life sciences where industry is not yet strong. After a time, these joint research efforts will not grow at the rates of the recent past because industry will internalize much of this effort as it begins to result in commercial successes.

I think you can see that our own internal basic research budget is already substantial, even in the face of the severe pressures to put more support into new products or even existing products. My point, therefore, is that industry and its research efforts are already severely strained. In addition, the costs of bringing some of the new technologies to the marketplace dwarf virtually anything we have seen in the past. For instance, Du Pont today is allocating 25 percent of its R&D budget to the life sciences. We are doing this even though many of the products we hope to bring forth may be a decade or more away. The risk of dry holes is very large.

In summary, I feel that it is unrealistic to view industry as a major, increasing source of basic research funds for universities. Rather, it is the Federal Government that must continue to play the key role here.

Let me turn now to note some policy issues at the Federal level which I believe importantly affect the environment for industry's mission in the national research effort.

Because of its effect on industrial research, tax law is a vital issue, just as is the level of Government funding for basic research at the university. Decisions about R&D are steered to some degree by the availability of depreciation allowances or tax credits and by assumptions about what the allowances will be several years hence, when today's projects in the lab begin to reach commercial production.

This year, the tax credit for R&D—or, more correctly, the credit for additions to R&D programs—is scheduled to expire. It went into effect in 1981 and will die unless renewed by legislation. Such credits are useful and productive and, like education, they can be expected to pay back their costs over the years. We, in Du Pont, would like to see the credits reauthorized and made permanent. We have a stake in the outcome. The credits have been a powerful capital formation provision for research-intensive industries and have been worth millions of dollars to companies such as Du Pont.

Several years ago, a more liberal investment tax credit was put into effect, and depreciation codes were changed to permit faster recovery of money invested in new plant and equipment. This sort of signal encourages private companies to crank up their technical efforts. Now, however, it is being proposed by the administration that we abandon the investment tax credit and stretch out the depreciation schedules. Whatever the reasons for the proposal, and whatever other effects it would have, this is one wrong thing to do if the Nation wants to encourage R&D.

Another key factor influencing industrial R&D is protection of intellectual property, both here and abroad. There is a direct correlation between the security of patent rights and industry's willingness to commit large sums to the inherently risky efforts needed to find and develop new technologies.

I can assure you the stakes are high. In my company, tens or even hundreds of millions of dollars stand behind some new products before they have been established in the marketplace. No company can put such funds at risk without patent protection that the courts and Government agencies will require the competitors to honor.

Last year, in a move that was most welcome in industry, Congress voted to restore some of the patent protection for pharmaceuticals. A similar provision should be made for agricultural chemicals. They also go through a prolonged testing process that consumes some of the useful life of the patent, and patent-term restoration in this area would be a stimulus to future R&D.

Government deserves credit for another move it made recently, and that is the 1984 law permitting more joint venturing in R&D. We in Du Pont do not expect to participate in many such ventures. We are attracted to a few joint ventures, but mostly these are with universities or other nonprofit organizations to stimulate pioneering work. Nonetheless, we support the new law. We believe it reflects a recognition on the part of the lawmakers that there is increasing international competition in technology, and that many other governments routinely encourage cooperative R&D. More such ventures in this country can lead to stronger technologies, and if the arrangements are made thoughtfully, no antitrust problems need be created. Joint ventures should prove to be more procompetitive than anticompetitive.

Let me sum up briefly. American research has been enormously successful in the past. I believe a large measure of this success is due to the way we have divided up the research task among Government, university, and industry. Basic research in science and engineering education are vital to our economic future and deserve maximum support.

Some support for basic research can come, and indeed is coming, from industry. But by and large, industry is fully committed in its research efforts to turn today's complex and rapidly evolving fundamental scientific discoveries into new products and the industries to produce them.

Industrial research needs a healthy overall economic climate. It is nurtured by many Federal policies. Two of the more important ones needing attention are R&D tax credits and improved domestic and international protection for intellectual property rights.

Mr. Chairman, that concludes my remarks, and I will be glad to answer questions.

[The prepared statement of Dr. Mac Lachlan follows:]

REMARKS BY

ALEXANDER MAC LACHLAN

DIRECTOR

CENTRAL RESEARCH & DEVELOPMENT DEPARTMENT

E. I. DU PONT DE NEMOURS & CO., INC.

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

OF THE

UNITED STATES HOUSE OF REPRESENTATIVES

WASHINGTON, D.C.

APRIL 24, 1985

Good morning Mr. Chairman and members of the Committee on Science and Technology. My name is Alexander Mac Lachlan, and I am Director of the Du Pont Company's Central Research and Development Department.

Let me say at the outset that I welcome your invitation to come here today.

While some of us may differ on style and emphasis, I am sure we are in general agreement that research is a vital part of American efforts to regain our international competitive edge and to get our trade deficit back down from the stratosphere.

In my opening remarks I want to comment briefly on how Du Pont manages its research and how at least one aspect of that process relates to the over-all national support of basic research.

The second area I want to note is government policy as it relates to the environment for industrial research.

Let me start this morning by saying that I think America has proven it does well in research. The informal partnership involving government, the university and industry is an effective alliance that meets our national needs within the context of the

American way of doing things. While our efforts reinforce and merge with each other, basically we have discrete roles. Government funds basic research, primarily through the university. The fruits of basic research in turn are developed primarily by industry into new products.

Industrial research is what I know best. Let me focus on that. Just as with every phase of industry, research is subject to rigorous budgetary review. At Du Pont, our R&D Budget supports 6,000 professionals with $1.2MMM for the current year. The decision and allocation process is complex, as the fundamental shape of the Company and its vision of the future is at stake. Let me give you some feel for this annual process.

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In the end the document is part of a master plan for the corporation's future. In Du Pont's case the budget is a prime vehicle to move our Company away from some of its historic businesses into new areas that include specialty chemicals and polymers, new products for agriculture, electronics and human health care.

We think of our research budget as composed of five parts: basic research which seeks new knowledge in areas of interest to the Company amounts to nearly 6 percent; discovery and development another 40+ percent as the area that is designed to get us into new businesses; and finally, support and extension at a little over 50 percent to keep existing businesses healthy. You can see that we regard science and technology and their practitioners to be our life blood.

Consequently, we believe that Federal science policy ought to assign highest priority to support for basic research and science and engineering education. This long range investment in trained people, knowledge and new ideas is an essential part of innovation and international competitiveness.

Almost inevitably, in this context the question arises of whether industry can or should do more to help basic research at the university. National Science Foundation estimates about $6.5 billion of basic research is performed in universities, with roughly $280 million being support by industry. While I won't say that we are at the limit of industry's ability in this area, my personal feeling is that getting much more basic support for universities via this route is not realistic.

There is no doubt that industry has a role to play in helping the universities. What is not always recognized is that industry already is an important factor on the campus. My own Company for example will donate some $16MM this year to promote science and engineering education and to support basic research at the university level. That support is in addition to the basic research we do in our own laboratories.

Many other companies have their own programs to assist universities. Included in this area are a number of joint industry-university entrepreneurial partnerships involving scientific research. Ultimately these may provide an important infusion of new funds into the university-scientific community. But I should point out that this sort of industry investment will flow largely into the newer and more critical areas such as the life sciences where industry is not yet strong. After a time, these joint research efforts will not grow at the rates of the recent past because industry will internalize much of this effort as it begins to result in commercial successes.

I think you can see that our own internal basic research budget is already substantial even in the face of the severe pressures to put more support into new products or even our existing products. My point, therefore, is that industry and its research efforts are already severely strained. In addition, the cost of bringing some of the new technologies to the marketplace dwarf virtually anything we have seen in the past. For instance, Du Pont today is allocating 25% of its R&D budget to the life sciences. We are doing this even though many of the products we hope to bring forth may be a decade or more away. The risk of dry holes is enormous.

In summary, I feel that it is unrealistic to view industry as a major, increasing source of basic research funds for universities. Rather it is the Federal Government that must continue to play the key role here.

Now let me turn to note some policy issues at the Federal level which I believe importantly affect the environment for industry's mission in the national research effort.

Because of its effect on industrial research, tax law is as vital an issue as is the level of government funding for basic research in the universities. Decisions about R&D are steered to some degree by the availability of depreciation allowances or tax credits, and by assumptions about what the allowances will be several years hence, when today's projects in the laboratory begin to reach commercial production.

This year, the tax credit for R&D -- or more correctly, the credit for additions to R&D programs -- is scheduled to expire. It went into effect in 1981, and will die unless renewed by legislation. Such credits are useful and productive, and like education, they can be expected to pay back their costs over the years. We in Du Pont would like to see the credits reauthorized and made permanent. We have a stake in the outcome: The credits have been a powerful capital formation provision for research-intensive industries, and have been worth millions of dollars to companies such as Du Pont.

Several years ago, a more liberal investment tax credit was put into effect, and depreciation codes were changed to permit faster recovery of money invested in new plant and equipment. This sort of signal encourages private companies to crank up their technical efforts. Now, however, it is being proposed by the administration that we abandon the investment tax credit and stretch out the depreciation schedules. Whatever the reasons for the proposal, and whatever other effects it would have, this is one wrong thing to do if the nation wants to encourage R&D.

Another key factor influencing industrial R&D is protection of intellectual property, both here and abroad. There is a direct correlation between the security of patent rights and industry's willingness to commit large sums to the inherently risky efforts needed to find and develop new technologies.

I can assure you that the stakes are high. In my company, tens of even hundreds of millions of dollars stand behind some new products before they have become established in the marketplace. No company can put such funds at risk without patent protection that the courts and government agencies will require the competitors to honor.

Last year, in a move that was most welcome in industry, Congress voted to restore some of the patent protection for pharmaceuticals. A similar provision should be made for agricultural chemicals. They also have to go through a prolonged testing process that consumes some of the useful life of the patent, and patent-term restoration in this area would be a stimulus to future R&D.

Government deserves credit for another move it made recently, and that is the 1984 law permitting more joint venturing in R&D. We in Du Pont do not expect to participate in many such ventures. We are attracted to joint ventures, but mostly these are with universities or other nonprofit organizations, to stimulate pioneering work. Nonetheless, we support the new law. We believe it reflects a recognition on the part of many of our lawmakers that there is increasing international competition in technology, and that many other governments routinely encourage cooperative R&D. More such ventures in this country can lead to stronger technologies, and if the arrangements are made thoughtfully, no antitrust problems need be created. Joint ventures should prove to be more procompetitive than anticompetitive.

Let me sum up briefly. American research has been enormously successful in the past. I believe a large measure of this success is due to the way we have divided up the research task among government, university and industry. Basic research and science and engineering education are vital to our economic future and deserve maximum support. Some support for basic research can come, and indeed is coming from industry. But by and large industry is fully committed in its research efforts to turn today's complex and rapidly evolving fundamental scientific discoveries into new products and the new industries to produce them.

Industrial research needs a healthy over-all economic climate. It is nurtured by many federal policies. Two of the more important ones needing attention are R&D tax credits and improved domestic and international protection for intellectual property rights.

Mr. Chairman, that concludes my formal remarks. I will be glad to answer any of your questions.

DISCUSSION

Mr. **Fuqua**. Thank you very much.

As I gather from your statement, you mention on page 3 of the prepared statement that probably—you say your personal feeling is that we are getting much more basic research support for universities by this route from industry. I gather this is not realistic. Even with the tax credits and so forth, you don't think that——

Dr. **Mac Lachlan**. Well, as I tried to indicate, depending on whose numbers you look at these days, anywhere from 4 to 6 percent of the basic research support that universities get is coming from industry. I can see some more, but I can also assure you that we are actually besieged—and I think many others in industry will tell you this—by requests, and we have responded to them, but when you compare that, when you contrast that with the internal allocation problem, with the opportunities in front of us, you are really torn, and therefore, cannot devote a larger percentage of your budget to basic research and then to, in turn, farm a good portion of that to the outside, I think you can see the ability to manage it becomes looser and looser, and it is very hard to justify to ourselves and to our stockholders.

Mr. **Fuqua**. How much is enough research? You are affiliated with a rather large corporation. How does industry, and maybe from your own standpoint, without revealing any proprietary information, how does industry establish research support levels, and are there any guidelines?

Dr. **Mac Lachlan**. I don't know what the number would be, but I think—

Mr. **Fuqua**. It would vary from industry to industry, I am sure.

Dr. **Mac Lachlan**. I am sure it does. But research is really only one piece of the whole part of industry. Funds have to go into capital investment; funds have to go into marketing and so forth; and, of course, ultimately, we have to make a profit in order to pay the stockholders for their support.

So how much is enough is very hard to say. In a static situation, I think one can come out with a reasonable balance among those various constituents. But occasionally, and hopefully more often, a new opportunity comes along, and then I think a company will actually step up its research.

I am thinking back in Du Pont's history. I guess probably in the late 1960's we started to back off on research because we were at a very high level, primarily because we felt the technology we were backing really did not—and it was mainly polymer technology, commodity chemical technology—really did not justify the levels that we were putting into it, which were historic.

Then along came the energy crisis, and suddenly—we had been diminishing the amount of research. Along came the energy crisis and a whole new set of opportunities to use research to improve the bottom line, or at least to keep us competitive. So that resulted in a spurt. You were talking about that earlier.

But, in my own mind, that kind of spurt, that particular one, was really not research in the sense of putting new things that would be for the long term value of the corporation. It was mainly to keep us competitive in the light of the higher cost of energy. This started about 1977 or 1978, and we recognized that we were running out of really new things, so we made the decision then to decide what should we do with the company, and research stepping up was one of them, but not in the old historic areas but in some of the newer areas, and the fruits of this have been dramatic.

We now see polymers not as an old commodity but as a whole new specialty business, and in the foreseeable future, we foresee electronic materials. In our company, we are not in the electronics business, but we have a very large electronics materials business, over a billion dollars in sales, and, of course, the life sciences, which is probably the highest risk area that we have. It is really not turning much back to the company at the moment.

Mr. FUQUA. When you set the priorities, and you mentioned in your company, and I am sure it is the lifeblood of a company such as Du Pont, but how do you go about, say, discontinuing research projects?

Dr. MAC LACHLAN. Discontinuing? As I indicated, it is an iterative process, but we basically try to evolve a strategy for the company, and that is, how do we want to change the company? Then we look at our whole portfolio of what we have, and we look at those things that we can see in the longer term don't fit that strategy.

In that sense, we will look at businesses either that we are going to pare research way back and essentially just ride them down—that is one kind of decision we can make—or divest ourselves from them, sell them to somebody else whose strategy they fit because of their approach to the future.

Mr. RITTER. Will the gentleman yield on that?

Mr. FUQUA. Certainly.

Mr. RITTER. I think it is an important point because it is tough enough for industry to discontinue or to change direction, and I guess I would ask a corollary question to the chairman's, and that is, how does Government, or from your perspective can Government, and how does Government make changes in its research programs and priorities?

Dr. MAC LACHLAN. Well, that is a much harder question, but I would——

Mr. FUQUA. Let me add another postscript to what Mr. Ritter said. We had a witness who had worked in Government, been director of a national lab and Assistant Secretary of Defense for Research and with industry today.

He was stating that the Department of Defense—and they were dealing more in the applied area like you would in your company—that they tried to determine, when a proposal came in from somebody about a new project, when do we work out of this project? When is the end of this?

Do you do that in industry? I didn't mean change the whole concept of the company, but do you have certain projects, maybe $1 million, $2 million, or whatever the figure might be, that you would suddenly decide, that's not working out; we don't see an end to that; how do we change?

We are faced with that, as Mr. Ritter pointed out, in the Government. How do we work out of some of these projects, or do you keep on and on and on for 50 years?

Dr. MAC LACHLAN. I think it is much easier for us because we are generally going toward a known end point, and the end point has parameters on it. We have to see that we are going to earn so much, and we keep testing those assumptions as we go along in the development. We have to see that the market has not changed out from under us, which occasionally happens. So it is by constant review versus the initial assumptions. Are the costs in line? If they are not—and they generally many times are not—can we still bear it? Is the carrot still there? Or has the market changed, or has some other new technology come in? Or—and this is not as common as the others—are there better places to put those people because this thing is taking too long?

So it is a combination of those things. But I would say the key is to review and review and review, and I mean on a frequent basis. In terms of individual research projects that are product-oriented, if they are of any complexity at all—that is, if they are in the more than just zero risk but you are just doing something because you know it will save you money when you finally get there, but I am talking about real risk type—bimonthly or two-monthly reviews are almost a necessity to keep on track. It is a hard process in that sense.

Now, as far as the Government goes, my own feeling is to go where the opportunity is and put your money where the opportunities are, and in thinking in terms of research, that means getting the best advice you can possibly get from the people who do research or use research and fund research. It is a combined thing.

But it is where the opportunity is at all times when you really come down to it. But you have also got to keep looking at it and be sure it is really there.

Mr. FUQUA. Mr. Ritter.

Mr. RITTER. Thank you, Mr. Chairman.

I have a question about the Government's regulatory policy and the potentially increasing liabilities deriving from that regulatory policy and how that impacts on a chemical company, how that impacts on your R&D investments, how that impacts on your seeking excellence and seeking competitiveness and seeking new products.

Dr. MAC LACHLAN. I think the liability is really, in many cases, a frightening thing to us. I think the drug company, as was reflected by the previous speaker, probably has about as great an example of that, although I guess the chemical industry distinguished itself not too long ago in India with a terrible situation.

So yes, liability is a grave concern. I have not seen it in our industry, at least, really stop us from anything, but it sure results in an enormous amount of analysis and, I would say, draining of intellectual energy in looking at things from the safety standpoint.

On the other hand, I come from a company where it has been second nature since I was there and long before that, and that is that we certainly do not want to do something that is unsafe for lots of reasons. We think it is an economic benefit to us independent of the liabilities.

But as we get into the drug industry—and as you probably know, Du Pont is in the medical, the health industry, but not in a large way as the Mercks and some of the other large pharmaceutical companies are—this is becoming more and more of a concern.

Mr. Ritter [as acting chairman]. What about Superfund liabilities and RCRA liabilities and TOSCA liabilities and the new expanded potential $13 billion Superfund?

Dr. Mac Lachlan. I think the impact of those—initially, of course, we all worried about the tremendous costs and whether the cost-benefit was still there, and I think we still do. But on the other hand, I think we are all responsible citizens, and as long as the liabilities are spread and everybody has the same responsibility, I don't see it as something that makes us noncompetitive.

In the international marketplace, you have somewhat of a different situation.

Mr. Ritter. Have you had a chance to study the $13-plus billion Superfund bill that has been introduced?

Dr. Mac Lachlan. I have not. No, I don't know much about it.

Mr. Ritter. I was concerned about that.

If you could, for the record, would you respond to what impacts that kind of feedstock and waste end tax and expanded liabilities would have on your R&D investments and your seeking new products?

Dr. Mac Lachlan. I would be happy to do that.

[See appendix 2 for response.]

Mr. Ritter. You mentioned that right now the R&D supported by industry and universities—is that a kind of limit? Do you feel that limit? I sense it. Are there other incentives to either supporting greater amounts of university R&D from industry or greater amounts of R&D in industry itself that we should be thinking of here in the Federal Government?

Mr. Mac Lachlan. I really cannot comment on what other incentives there might be. Obviously, anything that——

Mr. Ritter. Let me be a little more specific. Again, in looking at the Japan example, industry does almost a lion's share of the research. Not that much is done by the Government. In many cases it is a collaborative research. In many cases, when new products are developed, technological hurdles are collaborated upon, and maybe 6 or 10 areas are collaborated upon, and the product then is produced and separate companies go their separate highly competitive ways.

Should this country be doing more of that, or is Du Pont too big an institution to ask that question of?

Dr. Mac Lachlan. Well, I don't think it is that. I guess I was trying to think—I know this is what Japan does, and certainly they have been tremendously successful. I almost view what they have done as more of a fantastic marketing job or a customer sensitivity job than a technical job, and I think that as time goes on, unless they develop their own base to be able to supply technologies and new basic information, they are going to have problems.

I get very worried. You were talking about what might be an incentive, say, to have American industry give more direct support to the university. I get very worried about that from the standpoint of influencing the university unduly, as opposed to allowing it free rein and for the intellectual people in the universities to decide where they——

Mr. Ritter. Could I interject at that point? If 4 to 6 percent of the research at the universities is being covered by industry, that assumes that 90-plus percent is being covered by the Federal Government.

Dr. **Mac Lachlan**. And other sources.

Mr. **Ritter**. And other sources, but almost entirely the Federal Government. So what you have is not necessarily a free and spontaneous combustion of the best possible ideas, but you have a Federal R&D economy, a Federal R&D establishment that, going back to the chairman's previous question, that maybe finds difficulty in shifting or changing as networks are built up, as momentum is built up.

We are not the most changing of sorts here in the Congress in our funding patterns. In fact, when we do change, it is probably for the wrong reasons. So could you comment on that?

Dr. **Mac Lachlan**. Well, again, I agree with you, and certainly 4 to 6 percent from industry doesn't sound like it is a dangerous control or a dangerous influence, and it certainly is not, and certainly doubling that, if we were to imagine a number like that, I don't think would frighten anybody too greatly, either.

I think, though, that there is a big difference between the way industry in general, I think, interacts, if it played more and more of a role with the university and the way the Government interacts. I think, as best I understand it, the Government uses the advice of a broad constituency of various scientists and other things, and I think that is——

Mr. **Ritter**. If I may interject, it does that, yes, but it does that to some extent at the margin, so that a marginal percentage of the Government's programs will be undergoing a shift and a change, but to some very large extent, the bulk, the interior is what has been going on for some time which has vested interests.

I just want to point out that the Government is not simply a repository for basic research defined by an unbiased intellectual competition.

Dr. **Mac Lachlan**. There is no doubt about that.

Mr. **Ritter** [acting chairman]. Thank you.

I think that will be all, and I thank you for your testimony. I think it is quite helpful.

Dr. **Mac Lachlan**. Thank you.

Mr. **Ritter**. I would like to call Dr. Eugene E. Yore, vice president of precision weapons operations, Defense Systems Division, Honeywell, Inc., Minneapolis, MN.

Dr. Yore was the former project manager of the Task Force on Research and Development of the President's Private Sector Survey on Cost Control, the so-called Grace Commission, and we welcome you to the Science Policy Task Force, Dr. Yore.

[A biographical sketch of Dr. Yore follows:]

Dr. Eugene E. Yore

Dr. Eugene E. Yore is Vice President of Precision Weapons Operations at Honeywell's Defense System Division, Minneapolis, Minnesota. Prior to this position he was Corporate Director of Design Automation and Program Manager of the Research and Development Task Force of the President's Private Sector Survey on Cost Control. From 1975 to 1981 he served as Deputy for Science and Technology to the Assistant Secretary of the Army for Research, Development and Acquisition. His assignment prior to the Army was Director of Research at Honeywell's Systems and Research Center. He started his career as a research scientist and held various management positions at the Honeywell Systems and Research Center prior to becoming Director. Dr. Yore received his M.S. and Ph.D. degrees from the University of California Berkeley and a BSME from Ohio State University.

STATEMENT OF DR. EUGENE E. YORE, VICE PRESIDENT OF PRECISION WEAPONS OPERATIONS, DEFENSE SYSTEMS DIVISION, HONEYWELL, INC., MINNEAPOLIS, MN; AND FORMER PROJECT MANAGER, TASK FORCE ON RESEARCH AND DEVELOPMENT, PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL [GRACE COMMISSION]

Dr. YORE. Thank you.

Mr. Chairman and members of the Science Policy Task Force, I commend you on a most ambitious and important undertaking, as defined by your agenda, and I thank you for the opportunity to contribute.

We have prepared a written statement for the record, and I will briefly summarize that and would be pleased to respond to questions.

Our recent experience includes both industry and government, as director of research at Honeywell and as a top Army scientist and technology management position, and then most recently with the Grace Commission.

In our statement, we have focused on management, not on who should get how much. Everybody always wants more when it comes to resources, and our focus has been on how to better manage those resources to get better results for our dollars.

I would like to say that from my experience I think the management of the Federal R&D budget programs is an incredibly complex job, and in our experiences we have found many outstanding people working extremely hard to do a good job, from Congress all the way down to scientists in the laboratories.

In comparing the Federal science and technology with industrial science and technology management, significant differences exist on two fundamental management elements: goal setting and organizational structure.

We believe that Federal science and technology management could significantly improve by better goal setting and a better goal-setting process and a better organizational structure. Dr. Mac Lachlan was talking about end points and using end points that we define in industry as a basis for stopping research programs that have passed their usefulness, and to do that, you have to know what those end points are, or those goals, and have a consensus to them.

I think changing either the Federal Government's goals or the organizational structure requires the support and the involvement and leadership of you gentlemen and the executive branch.

In the past, when this country has had a clear, measurable, specific achievable goal with a completion date, we have accomplished fantastic things. We have sent a man to the moon and developed nuclear weapons, nuclear power. But for many years, we have had many billions of dollars invested in programs that have muddled along without a clear end point, without knowing where they were going, how we would know when we got there, what direction, how much to invest, how fast to go, what the alternatives were and what to stop doing.

We found during the course of the Grace Commission study that a number of departments had excellent strategic planning processes in place and were having a great deal of difficulty in using them to manage their business because of the lack of clear, sharply defined goals that had the consensus of the Congress and the White House.

In my opinion, strategic planning and the management of the Federal R&D or science and technology could be easily accomplished if we paid more attention to setting clear, specific goals with specific end points.

I have included in a pass-out an example of about seven or eight different goals that we have looked at in the course of the Private Sector Survey Study, and we found that a number of programs were attempting to set goals for themselves and get a consensus behind those goals, but they were missing important elements of a good goal.

Although goals and strict discipline in planning and executing those goals should be the rule, not the exception, it would be a mistake to enforce that 100 percent. Science and technology management need some flexibility to exercise judgment in executing specific science programs. In many cases, breakthroughs and discoveries do not exist in the current structure, are not consistent with the current wisdom or proven concepts, and we have to not overmanage.

At Honeywell, we have an effective means of allowing management judgment and flexibility and still managing with a strict discipline. It is a program we initiated about 5 years ago called the Initiatives Program.

Research management takes about 10 percent of their total investment funds and puts it in an initiative program. Each technical person in the organization is encouraged to submit proposals for those funds. Those funds are apportioned by a group, a committee of peers outside the normal management channel, and in the 5 years, many innovative new concepts and programs and future potential businesses got their start in the Initiatives Program.

Also, in the Department of Defense, there is the inhouse laboratory independent research program, which is a similar Initiatives Program. When we were connected with the Army, we started allocating those funds based solely on how well they were used last year, not a proposal for the future, and gave the laboratory managers a great deal of flexibility in deciding how they allocated those funds.

When they reported 100-percent success in their allocations, they were not taking enough risks, and if they did not succeed at accomplishing anything, they were taking too much. Again, there were a great number of scientific breakthroughs that started in that program.

So my message on goals is that we need to set them; we need to know where we are going so we will know how fast to go and when we get there; and we need to manage with the discipline to do that but not to the extreme of stifling all innovation and flexibility of managers.

The second startling difference between industrial research management and the Federal Government science and technology establishment is the organizational structure. When I was Deputy for Science and Technology to the Secretary of the Army, there were 11 layers of management between myself and the laboratory director. We have recently counted 19 levels of management between a scientist at an Army lab and the Under Secretary of Defense for Research and Engineering.

At Honeywell, we have seven. We have looked at Bell Labs, Hewlett-Packard, and a number of other companies, and there are six or seven or eight layers between a scientist and the chief executive officer.

It is not so much the number of people, it is the efficiency of the decisionmaking process that suffers from a large number of layers of management. Somebody has suggested that the number of days to get a decision made is proportional to the square of the number of levels of management.

If you look at going from a scientist to a chief executive officer at Honeywell and six levels, that adds up to about 25 days. If you look through going at 19 levels, it comes out something like 361 days. I don't know if that is always validated by true cases, but I suspect that it is close.

The second conspicuous difference between the organizational structure in industry and Government science and technology management is the use of staff assistants. In industry, we don't have many, don't have any in a lot of cases. In Government, there are many.

I suggest that if you pick up any agency's telephone book and look at who is the line management and who is the staff supporting the line management, you can get as many as 10 staff assistants per line manager. Again, it is not the number of people that causes the inefficiency; it is the erosion of the line management authority to make decisions and execute the strategic plan to achieve the goals.

In industry, when we have a catastrophic failure, we know which line manager to go fire. I think it was President Lyndon Johnson who, upon finding that one of his pet projects had been scuttled by someone in a department somewhere, said, "Fire him? Hell, I can't even find him." I think that is a symptom of having a lot of staff and not clear line management.

I think there are two notable examples that I would like to commend of recent Government actions to change that. One was the State of New Jersey and Governor Kean back in 1982. He commissioned a study of outside consultants and inside government people to look at the State organization and compare it to industry. They discovered that they had one manager for every 4.5 employees or workers, compared to about 6 in industry. They took on a specific goal of moving from a ratio of five employees per manager to seven employees per manager.

In the course of 1 year, they made a significant step toward achieving that. They made it about halfway in 1 year. And again, they did not do that by firing people or letting people go. It was changing the organizational structure and having more people report to each supervisor up the chain. It cuts the number of excessive layers of management between people who get the job done and the top people who set the goals and the direction.

A second that I would like to commend is that of Secretary of the Navy John Lehman. Recently he announced that he was ending the Navy Material Command and dissolving that organization, again with about 2,000 people, and again not necessarily getting rid of people but organizing differently to get the job done and tighten up the organizational structure and make it possible for line management to have the authority they need to carry out their responsibilities.

In both cases—I don't want to be misinterpreted—I am not talking about having too many people to manage the Federal R&D; I am talking about the way they are organized.

I think those are the main points in my statement. I am prepared to respond to any questions.

[The prepared statement of Dr. Yore follows:]

TESTIMONY OF DR. EUGENE E. YORE,
VICE PRESIDENT OF PRECISION WEAPONS,
HONEYWELL DEFENSE SYSTEMS DIVISION
TO THE COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES,
ON THE RELATIONSHIP OF INDUSTRIAL
BASIC AND APPLIED RESEARCH
TO GOVERNMENT SCIENCE POLICY

APRIL 24, 1985

1.0 INTRODUCTION

The subcommittee on Science and Technology requested a statement on three broad topics concerning the relationship of industrial and applied research to government science policy. The topics are: 1) methods of industrial research management 2) Industrial support for basic and applied research, and 3) supply and demand in industry for several and engineering. We believe the most potential for improvement exists in government's management of science and technology and have focused this paper on the first topic.

Our experience both in industrial and government service and technology management suggests that we might obtain improved results for our federal investment if:

1. The Executive Branch would clearly state "good" goals.
2. The congressional process would focus on achieving a concensus on goals.
3. The agencies would define strategic plans and manage to them with strict discipline.
4. The federal research and development ogranizational structure could be tightened up.

In other words, the three most important deficiencies in federal research and development are: goal setting, strategic planning and organizational structure. These are fundamental management functions and we believe there are lessons government can learn from industry concerning them. We also address in this statement information requested; Honeywell's participation in Microelectronics and Computer Consortium, our University support programs and infomation on the level of our research and development spending.

Ed Spencer, Chief Executive Officer of Honeywell Inc, aptly expressed the thrust of how federal agencies might be improved by learning from industry's experience in managing research programs.

> There is a body of thought which is urging the federal government to set long-range goals and strategies for the nations's future, and then to target research and development for all agencies to accomplish these objectives in broad terms, rather than negotiating research and development on an annual basis through countless line items in the budget. While such a proposal may be politically difficult to achieve, it should be discussed and pushed.(*)

1.1 GOAL SETTING

Federal research and development efforts could yield better results by giving more attention to setting good goals and achieving a stronger, more lasting concensus on those goals. Strong goals facilitate the development of research and development objectives and funding levels, guide the selection and ranking of government-sponsored research and development efforts and improve the overall stability of research programs.

(*) Ed Spencer, 1983, "U.S. - Japan Trade Investment Issues: A case against protectionism and for a more competitive America", presented to the governing board of the electronics industries association, Phoenix Arizona, January 1983.

When the science and technology community focuses on good goals, the range of possible accomplishments is almost unlimited. The commitment to put a man on the moon within the decade is an illustration of a good public sector goal-setting process. Our national prestige was declining at home and abroad. The President's advisors determined that a grand demonstration of our technical superiority--such as putting a man on the moon--could capture the imagination of the world and redirect national attention to technical preeminence. Technical experts advised that the goal was feasible and had scientific merit. A congressional concensus was formed and programs consistent with goals were funded to accomplish the objectives. This top-down, bottom-up concurrence on desirability and feasibility along with continuing congressional concensus enabled the government to focus the scientific capability with spectacular results. Contrast this with the War on Cancer. Curing cancer is obviously a worthwhile goal but, at the time of its announcement as a federal goal, it had not been demonstrated to be technically feasible. Expending $3.6 billion did not make it any more feasible.

The President's Private Sectors Survey on Cost Control R&D study showed that although there are some examples to the contrary, the majority of agencies have been unsuccessful at setting effective goals. Figure 1 summarizes a few examples of government research program goals rated according to basic industry criteria for effective goals. It shows that many federal programs lack two or more of the basic elements of good goals.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
Air Land Battle 2000	No	No	No	Yes	Maybe
National Space Policy	No	No	Yes	Maybe	Maybe
National Heart Lung and Blood Institute	No	No	Yes	Yes	Yes
National Energy Policy Plan	No	No	Yes	Yes	No
Magnetic Fusion Energy	Yes	Yes	Yes	Yes	Maybe
Man-Moon-Decade	Yes	Yes	Yes	Yes	Yes
Manhattan Project	Yes	Yes	Yes	Yes	Yes

Figure 1. Examples of Federal Goals Compared to Basic Industry Elements of Effective Goals

Although industry has by no means mastered the art of goal setting, the President's Private Sector Survey on Cost Control study suggested that industry on the whole is doing a better job than government. That is because we believe that long-range goals are essential to achieving and maintaining a profitable business.

In industry, the process as well as the goals themselves, requires constant examination and emphasis. Top management cannot develop goals separately from the line managers responsible for strategy and implementation. Similarly, line managers cannot focus adequate resources to achieve long-range goals they set by themselves. They need top management's concurrence on funding resources and authority. A continuous, intensive strategic planning process is typical in the private sector.

Rationale for goal setting and some criteria for effective goals and recommendations as to how to improve the government goal setting process are included in the President's Private Sector Survey on Cost Control and will not be reiterated here.

1.2 Strategic Planning

The President's Private Sector Survey on Cost Control Research and Development study found that excellent strategic planning processes exist in many government agencies. What they most often lack are the goals and concensus that must be the cornerstone of effective strategies planning. Goals and a strategic planning process are even more important in the management of government research and development since it is more complex than industry, in part due to the large number of individual programs, laboratories, and agencies. Also, Presidential appointee positions tend to turn over more frequently than the Administration. High turnover at the policy-making, decision-making, and management levels within all agencies further complicates the planning process by reducing continuity. Goals and strategic planning yield stability and constancy of purpose.

Techniques for managing long-range planning have grown a good deal more sophisticated during the past decade. While the terminology and application vary, strategic (or long-range) planning refers to the process of determining near-term actions in the context of long-range goals and economic constraints. In research and development management, the process is used to plan and execute each year's research and development actions to assure that future needs are met with focused and timely research and development actions.

Most corporations start by analyzing economic conditions and their projected market posture for 10 or 15 years into the future. This exercise helps executives set specific goals and objectives. They then develop detailed plans with task and program definitions, budgets, and schedules, emphasizing the required near-term actions. These plans usually are produced by an iterative process involving many levels of management. They are used to establish and maintain audit trails for progress evaluations, are not changed without top management concurrence, and are reviewed periodically by top management.

The President's Private Sector Survey on Cost Control outlines the benefits and payoffs of strategic planning and recommends an approach to implementing such a process within the federal government.

Once a stable planning process is in place with strategies and funding levels tied to goals, there still remains the need for scientific and technical management judgement and flexibility. This is particularly true in science, where new breakthroughs or discoveries are not always based on proven concepts and where national payoff is not always predictable. At Honeywell, we have one effective way to instill some management judgement and flexibility into the research and development strategic plan. It began five years ago at one of our research centers and has been implemented in various forms in other parts of Honeywell.

The Systems and Research Center is a $40M research and development facility whose mission is to advance the state-of-the-art in technologies necessary for the future products of the eight Aerospace and Defense Businesses of Honeywell. EAch year this research center conduct a review and update of their strategic plans with each division. The review includes consideration of their goals and strategies in each technology area, desirability of adding/deleting technology areas, and expected divisional payoffs. The key in all cases is to establish a concensus between the research center and each division on mutual technology goals and strategies. This concensus then guides the research center in formulating their programs for the following year. If not carefully implemented, such a process could result in inappropriately low risk plans, loss of creativity among the technical staff and an overly rigid organization unable to flexibly respond to technical breakthroughs. To avoid these pitfalls, SRC management developed the Initiatives program.

In this program, management sets aside a fraction of their internal research and development budget (10% then, 15% now) to support the investigation of technologies which SRC considers important to Honeywell's continued long term success, but which have not been identified by a Division as a high priority need. All technical employees are encouraged to submit project proposals and funding decisions are made by a committee which includes a cross section of management, technical and marketing personnel. This "seed money" program has proved to be an effective way to maintain an appropriate level of technical risk in the annual program and support "far out" yet relevant technology advancements. In its five year history, several outstanding results have been realized. Figure 2 gives a list of successful Initiatives programs and their potential payoff to Honeywell.

1.3 Organizational Structure

Many government research organizations suffer from excessive layers of management, narrow spans of control, particularly in middle management, and an extensive use of assistants to replace or supplement line management functions.

The expense of this excess if far greater than the cost of the people. It prolongs decision making and undermines managers' ability to make decisions they are responsible for making. We are not saying there are too many people

PROJECT	PAY-OFF
Spectrally Agile Sensor System	Space Surveillance contracts with Government
Real-time Video Display Generation	Computer Generated Synthesized Imagery contract
Key Driven Architecture	Honeywell entre into secure computing market
Characterizing & Propagating Uncertainty in Large Scale Systems	Two research contracts in Systems Analysis
Man in Military Space	Space Station contracts from Rockwell and NASA
Semiconductor Superlattices	An Air Force research contract in Infrared detector materials
Coherent CO2 Laser System	Patent

Figure 2. Examples of business pay-off of Honeywell's Systems and Research Center Initiatives Program.

in the federal research establishment; on the contrary, there may not be enough. We are only saying that they are organized contrary to accepted guidance for span of control.

A study done in as in adjunct to President's Private Sector Survey on Cost Control determined that there is one manager for every 4.5 workers in the federal government, compared to a manger for every 6.1 workers in the private sector.(*) This management overhead, when summed up over 2 million government workers represents a significant opportunity to reduce government costs. According to the study mentioned above, up to $6.2 billion per year could be saved by 1986 if the government management structure more closely matched those of the private sector.

The data show for example that a conservative estimate of the number of assistants in the 13 cabinet level agencies is 1388, that management spans of control are significantly broader in the private sector, and that government managers could improve their effectiveness (as compared to industry) at all levels by anywhere from 14.6% to 43.3% (Figures 3 and 4).

(*) Boldock, S.P., Coombs, C., Pope, R. and Ueltzen, R., Organizational Fat in Federal Agencies, unpublished special study of the President's's Private Sector Survey on cost control, May 1983.

Federal Government Span of Control		Industry Span of Control
1:3.7 *	SENIOR MANAGEMENT	1:5.5
1:3.0	MIDDLE MANAGEMENT	1:4.3
1:7.1	FIRST LEVEL MANAGEMENT	1:9.5

*Each manager manages 3.7 functions

Figure 3. Spans of control in the federal Government as compared with Industry. Data derived from a President's Private Sector Survey on Cost Control adjunct study.

	FEDERAL GOVERNMENT (13 CABINET) level agencies	NEW JERSEY		INDUSTRY (Companies interviewed)
		Before	After	
# Levels	11.4	9	6	8.7
Span of Control				
o Senior Mgmt	1:3.7	NA	NA	1:5.7
o Middle Mgmt	1:3.0			1:4.3
o First-level Mgmt	1:7.1			1:8.9
Assistants				
o Secretary	88			
o Deputy Sec'y	38	NA**	NA**	
o Undersec'y	321	NA	NA	
o Asst. Sec'y	95			Not Applicable
o Administrator	271			
o Staff	154			
o Senior Mgmt	248			
o Middle Mgmt	173			
% Managers	18.2%	16.7%	12.5%	14.0%

* Before and after relates to the Management Improvement Program instituted by Governor Kean in June of 1982. The "before" is June 1982 data while the "after" is the June 1983 goal.

** Not available - but very few if any.

Figure 4. Levels of management and spans of control in the federal Government as compared with the State of New Jersey before and after the New Jersey Management Improvement Program and as compared with industry. Data derived from a President's Private Sector Survey on Cost Control adjunct study.

We are confident that a concerted effort to improve this situation can have payoff. A dramatic indication of this is the State of New Jersey Management Improvement Program. Established in 1982 and relying on a consortium of consultants from the private and public sectors, this program is in the process of increasing ratios from 1 manager per 5 workers to 1 manager per 7 workers (Figure 4).

1.4 A Comment on the Microelectronics Computer Consortium.

This section summaries Honeywell's assessment of MCC, the Microelectronics and Computer Consortium, as a means of managing research and development. Honeywell is benefitting from its investment in the Microelectronics and Computer Consortium and strongly supports it. The rationale to establish Microelectronics and Computer Consortium was certainly well founded. It was a response to a similar Japanese organization aimed at developing the fifth generation computer and by doing so, positioning Japan to capture the future American computer market. The Microelectronics and Computer Consortium was established by 12 corporations, including Honeywell, as a way to pool resources and technical talent and work together to share risk in common technology developments. The Microelectronics and Computer Consortium's goals are long range research, not products, and each corporation shares in the output and gains leverage on its investment.

The Microelectronics and Computer Consortium, now in its second year, is meeting it early goals and Honeywell management is pleased with its process. So far, it has pulled together a competent organization (40% of which came from the participating corporations), and rational goals and strategies have been established. The number of corporations involved has increased from 12 to 21. There is an effective review process at all levels of the organization. The key to the ultimate success of the Microelectronics and Computer Consortium rests in its ability to transfer technology to its shareholders. Technology transfer is usually a difficult challenge in research and development, a fact that the Microelectronics and Computer Consortium recognizes.

1.5 Industrial Support of University Research

Included in this section are comments on Honeywell's experience in supporting university research. There has been a definite positive trend in the past few years toward greater cooperation between universities and industry. Universities are becoming increasingly willing to design research programs to be more relevant to industry needs and industry, on the other hand, has begun to provide longer term support thereby adding growth and stability to university projects. At Honeywell, support takes many forms and is given by several groups within the corporation (Figure 5). Honeywell chooses the institutions it supports on several criteria, but for the most part, all funding goes into technologies that are critical to the business.

University affiliations are the most common type of program funded by Honeywell. Smaller affiliation programs, funded at the $15,000-$40,000 level, benefit Honeywell by keeping us in touch with the most current research in areas of interest. The specific benefits are shown in Figure 6. These small grants provide universities with funding that is not tied to specific industry goals and tends to support more "basic" kinds of research, such as equipment, graduate research and training, etc.

SOURCE OF FUNDS FOR DIFFERENT TYPES OF CONTRIBUTION

Types of Donation \ Source of Funds	Honeywell Foundation	Corp. Budget	Div. Budget
Affiliate/Associate Program	X	X	X
Cash Donation	X		
Fellowship	X		
Award	X		
Matching Gift	X		
Sponsored Research		X	X
Design Participation			X
Use of Ind. Facility			X
Special Event	X	X	X
Resident Scientist		X	X
Seminar/Lecture		X	X
New Equipment Donation	X		
Software Donation	X		

FIGURE 5

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TYPES OF CONTRIBUTION
VS
OBJECTIVES FOR CONTRIBUTION

Objectives Types of Donation	Recruiting	Tech. Access	Emply. Benefit	Corp. Citizen	Tech./Bus. Image
Affiliate Program	X	X	X		X
Cash Donation	X	X	X	X	X
Fellowship	X		X	X	X
Award	X			X	X
Matching Gift			X	X	
Sponsored Research	X	X	X		
Design Particip.	X	X	X		X
Ind. Facility	X	X	X		X
Special Event	X			X	X
Resident Scientist	X	X		X	X
Seminar/Lecture	X			X	X
New Equipment	X			X	X
Software	X			X	X

FIGURE 6

The larger affiliation programs, which generally involve investments of over $100,000 are the second type of program supported by Honeywell. Examples are the Microelectronics and Information Science Center at the University of Minnesota, the Center for Integrated Systems at Stanford and the Semiconductor Research Institute in the Research Triangle in North Carolina. These longer programs are co-sponsored by several corporations and generally support more fundamental (as opposed to basic) research; that is research aimed at specific technology advancements of interest to the sponsoring corporations.

We feel that both types of programs are important for US competivness and national security and Honeywell intends to continue its participation in such programs.

1.6 The Honeywell Research and Development Investment

Figure 7 is an historical account of levels of research and development investments at Honeywell. The trend, as the chart shows, is a significant increase in our investment level over the past several years. Our research and development expenditure in 1984 was $422M, or 6.9% of revenue. Although Honeywell ranks 65th in sales among the Fortune 500 companies, we rank 15th in our research and development expenditures to revenue. This fact is due to the high technology content of Honeywell products. Also shown in Figure 7 in the level of government funded research and development within the company. About 90% of the total government research and development funds programs within the Aerospace and Defense groups of Honeywell.

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	1977	1978	1979	1980	1981	1982	1983	1984
Revenue	2911.1	3547.8	4209.5	4869.7	5261.3	5387.1	5667.4	6073.36
Honeywell Funded R&D	152.3	187.2	234.6	287.0	362.8	386.4	414.1	422.0
R&D Honeywell/Revenue	5.2	5.3	5.6	5.9	6.9	7.2	7.3	6.9
Government Funded R&D	154.5	136.5	188.9	295.6	320.2	353.9	348.5	390.5
Government R&D/Revenue	5.3	3.8	4.4	6.0	6.2	6.7	6.1	6.4

Figure 7. Historical trend of Honeywell Revenue compared to internally funded and Government funded Reseach and Development.

Mr. RITTER. Thank you, Dr. Yore.

In sum, how would you characterize the Federal R&D managed efforts with those in industry? How would you compare them?

Dr. YORE. In the Federal R&D management, it is a much more difficult process, difficult task. It is larger, broader, less focused, and some of that is the nature of the Federal R&D task. I believe some of it is the lack of a process for achieving a consensus on Federal goals and in the organization structure, both of which I addressed.

It is not easy in industry, either. We can do better and try, but we have more ability to do that. We set goals at the top level and develop the research programs to support the achievement of those goals, and when our strategic plans drift off we know it and take corrective action.

Mr. RITTER. With regard to that, we worked from the Vannevar Bush Report of 1945, which advocated a far stronger role for the Federal Government in R&D, and we have certainly built that role over the years. Are we at the right balance? Have we gone too far? Did the Commission get any sense as to what the balance should be? Are we overly involved in a Federal R&D economy and not sufficiently involved in a more commercially oriented private R&D economy? Could you comment on that?

Dr. YORE. In the Grace Commission, we specifically avoided looking at policy issues and should it be more, should it be less. We were looking more at efficiency, at how could we manage what we have better.

My personal opinion is that it is hard to make a strong case for more expenditures. On the other hand——

Mr. RITTER. More expenditures where?

Dr. YORE. Of the Federal budget committed to science and technology.

Mr. RITTER. You would like to see those expenditures expand within the private sector?

Dr. YORE. I have difficulty making a case for increasing from the current level of the Federal expenditures. I think what we do expend can be done more efficiently and get better results.

Mr. RITTER. And if there is growth, you would prefer to see it take place within the private sector, R&D growth, I mean?

Dr. YORE. I guess I would not care to state that. I think in the private sector the level of R&D is driven by the business objectives and the achievement of those, and there is a natural check and balance that determines the level and its existence in delivering the profit objectives of the corporation.

I don't believe that the level of R&D in general needs to increase in industry. Specific companies might make the decision that yes, they need to increase theirs for some good business reasons and do that, but I have trouble with generalizing that.

Mr. RITTER. That is interesting.

Dr. YORE. If you look at Honeywell, we are the 65th in size in the Fortune 500, and we rank 15th in expenditures for R&D. That has gone from about 5.2 percent of our revenues in 1978 up to about 7.2 percent last year in 1984. It is down a little bit this year for some specific operating reasons. But we made the decision that we needed to increase, but that was a local decision, not one I would care to generalize to other people in our industry.

Mr. RITTER. In the Federal lab situation, there is quite a difference in the control over budgets that Federal lab directors have as opposed to industrial lab directors. The Commission recommended greater budget control for Federal lab directors. Having been through the budgetmaking process for Federal laboratories, it is a kind of tall order considering so many constraints are laid down, but could you comment on that?

Dr. YORE. The Federal labs—and I guess it is difficult to generalize. There is a difference between DOD and DOE. But in both cases, there are examples of laboratories that got started with a strong mission and a clear objective and made significant accomplishments in growth. Many of those, as time has passed, the reason they were created has been resolved or changed, and they have lost focus in their goals and mission. I think that is a significant problem, and I think that needs to be sorted out.

Mr. RITTER. I think that is a very important statement. There are billions of dollars a year that are defined, again in a Federal R&D economy, that are based on goals and priorities that were set, conceivably, decades ago, and there has been some adaptation, some massaging around the edges, some major shift when we went into the energy crisis. But we have, I think, grounds for some very significant progress coming out of this task force in terms of recommendations as to how to reevaluate the missions of the Federal laboratories, and I think the work of the Grace Commission will be helpful there.

I have been asked a couple of questions here. Could you perhaps comment about the—this is a side item, I suppose—but comment about the availability and quality of new engineers at Honeywell?

Dr. YORE. Yes. I would say at Honeywell, in general, we are getting the supply and the quality of engineers and scientists that we require for the business. There are specific technology areas where there is clearly a shortage—computer sciences and microelectronics and millimeter wave, infrared sensing—but in general, the supply and quality are there.

I was involved in developing estimates of future requirements when I was in the Army position, which we supplied to the National Science Foundation in their annual assessment, and I had a great deal of concern about the validity of those numbers are how they were generated. It was not very scientific, but there was a lot of judgment associated with it. I don't know how to do it better.

Mr. RITTER. You are saying that the National Science Foundation survey may not be as accurate as some in industry would like?

Dr. YORE. I don't think we can expect it to be better. I don't know how to do it better. But there is certainly a question about how accurate it is. It is a very difficult thing to project.

There is a long leadtime in getting teaching staffs built up in universities and a student flow through specific curricula. I think we have to continue trying. I think the National Science Foundation, what they do is good, and they need to continue doing it. I don't mean to criticize it, but it is a process that is not completely scientific and precise, and we have got to accept it that way and find ways to manage the variances.

One thing we do at Honeywell is we have a management development center both at the corporate level and at some of the group levels where we take people and retrain them to new technologies where we have shortfalls or train them when we are unable to get the supply of their appropriate skills.

Mr. **Ritter**. Dr. Yore, just one quick question. We have heard a lot about the problem that engineering doctoral programs are having at our universities. Particularly, U.S. citizens are not entering in, and there is a variety of comments as to why this is happening, and we have discussed them here in this very committee room. Do you have any ideas to offer as to why there is limited entry into these doctoral programs?

Dr. **Yore**. I think the salaries that a bachelor of science can command, or master of science can command, make it very difficult for a young person to decide to continue to get a Ph.D. I think it is a serious problem. I don't have a suggestion or a recommendation for how we change that.

Mr. **Ritter**. Is that a commentary on the marketplace alone, or is it a commentary on the nature of the engineering doctorate? We have heard some comments on that.

Dr. **Yore**. I meant it to be a commentary on the marketplace. I am not aware of any specific issues with the engineering doctoral programs.

Mr. **Ritter**. I would like to, just for a few moments, ask the staff if they have any outstanding questions that they would like to ask.

John Holmfeld.

Dr. **Holmfeld**. Thank you, Mr. Chairman.

You emphasized, Dr. Yore, the need—you emphasized and the previous witness also emphasized the need to set goals, and I am wondering whether you have any comments on how goals are set for basic research, both in industry and specifically in Government. What goals and how could one set goals for the funding and support of basic untargeted kinds of research?

Dr. **Yore**. In industry, the basic or fundamental research goals flow down from the top-level business goals on what do we strive for in growth rate and what business areas we focus on and what are the critical technologies or science areas for those specific business areas or products. So in industry, there is a fairly clear, rational line of rolling down from the business goals to the fundamental research goals.

It may be a little bit more difficult in the Federal science and technology to do that, but I think it has to happen in the same way. There needs to be some top-level consensus on what are the important areas—energy, national defense, economic competitiveness in a world market—and we need to flow down from there.

In the Grace Commission report, we suggested one process on how that might happen, but I am sure there are a number, and they would need to be developed by the people in place.

Dr. **Holmfeld**. Could I ask just one followup, Mr. Chairman? That is, other witnesses before the task force have told the members that in that area of basic research, a goal should simply be U.S. leadership in particle physics or any other discipline, or U.S. preeminence in a particular field of basic research, and then the question comes up, can and should a national goal for the United

States be leadership or preeminence across the board in most of the scientific disciplines, or should the United States try to be selective and, in a sense, divvy it up, let the West Germans be preeminent in certain fields of radioastronomy and the United States be leaders in particle physics, et cetera?

So do you have any comments on that?

Dr. **Yore**. Yes, I do. I know there is a body of thought that believes we should do research for research's sake, or we should have certain areas that we are best in. I happen to disagree with that, and I think we need to start at a top-level Federal Government position of national security defense, national security economic competitiveness, and flow down to there. It may be particle physics or it may be pharmaceuticals or it may be something else, but I think it has to start with a top-level goal.

Dr. **Holmfeld**. Thank you.

Thank you, Mr. Chairman.

Mr. **Ritter**. I would just like to comment on Dr. Holmfeld's question and Dr. Yore's response. I think that it is a very essential feature of this science policy debate what the driving forces are of the Federal R&D economy, what those major goals are, and how we set up our priorities to reach those goals.

If you have been around the Federal R&D establishment long enough, you realize that it is driven a great deal by the momentum from the past. It is driven a great deal by the momentum of big science, defense science, the energy crisis, and we are out on the edge dealing with the loss of industries in our districts, loss of jobs. That is from Silicon Valley, where his boss comes from, to Lehigh Valley, where I represent constituents.

I think this task force has a real role to play in helping to at least shift the terms of the debate from supporting an existing, ongoing science establishment to supporting those best estimates of where the battlegrounds are for industrial competitiveness domestically and worldwide.

Well, I thank you very much for your interesting testimony, Dr. Yore.

The task force stands adjourned until tomorrow morning at 9 o'clock, when we will meet to discuss international cooperation in high-energy physics.

Thank you. Thank you all.

[Whereupon, at 11:40 a.m., the task force recessed, to reconvene at 9 a.m., the following day, Thursday, April 25, 1985.]

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APPENDIX 1

Statement to the House Science and Technology Committee
on the Organization, Management, and Returns
from Industrial Research

Edwin Mansfield
Director, Center for Economics and Technology,
and Professor of Economics, University of Pennsylvania

1. Introduction

I am honored to have been invited to testify before this committee. The comprehensive review of American science policy that is being carried out by this committee will undoubtedly be of great importance. I have been asked to testify concerning the following two broad questions: (1) What are some of the salient characteristics of the organization and management of research by American industry? (2) What evidence exists concerning the effects of basic research carried out by industry and the changes over time in the proportion of industrial R and D expenditures devoted to basic research? My discussion of each of these questions must necessarily be very brief. More detailed treatments are found in the papers and books cited in the references. At the outset, note that I have been asked to focus on research, not development.

2. The Organization of Industrial Research

Firms organize their R and D activities in quite different ways. In large, decentralized firms, there is frequently a central research laboratory, which emphasizes research, and separate R and D departments in each of the operating divisions, these departments doing product and process development of a more immediate nature. There are advantages in separating the more fundamental work from the more short-term, since the organization, style of leadership, and constraints that are appropriate for more short-term work are often inappropriate for more fundamental work. However, it obviously is important that this separation does not result in too little communication between the advanced researchers and the people who are wrestling with problems of current design, manufacturing, and marketing. Otherwise, research findings may not be properly utilized, and research projects may not be chosen with proper reference to the firm's commercial needs.

According to a survey of 19 laboratories in the chemical, drug, petroleum, and electronics industries, about 58 percent of these laboratories have separate research functions and development functions, each with its own staff and facilities. A relevant variable in explaining why some laboratories tend to separate research from development whereas others do not is the relative equality of research expenditure and development expenditure. As research expenditure and development expenditure become more nearly equal, the need for the separation of research from development intensifies, while if research expenditure or development expenditure is very small relative to the other, there is much less need for separation.

Within a firm's central research laboratory, there is often a grouping of scientific personnel by academic disciplines or subjects. For example, the survey of chemical, drug, electronics, and petroleum firms indicated that research was organized more often along disciplinary than product or functional lines. The subject areas, which often parallel the fields of learning at educational institutions, naturally depend on the problems predominant in the firm. This disciplinary kind of organization makes it relatively easy for the researcher to keep in touch with others in the same subject field, it encourages him to keep up to date in his science, and it makes it easier to recruit outstanding scientists to the company.

3. The Management of Research

The administration and control of research tends to be looser and more informal than in most other areas of industry. Although there may exist a rather formidable formal control structure, many of the decisions tend in fact to be made quite informally. In research, but not development, it is generally believed that administrators should resist the temptation to manage projects in much detail. Usually, management's job is limited to providing general guidelines and goals, selecting capable persons, and providing a climate conducive to good work. But this does not mean that management does not--and should not--guide research. Whereas overmanagement of research is likely to lead to technical hack work, totally unguided research is likely to lead to waste and frustration. Firms that do well in this area learn to guide research in the directions most likely to contribute to company goals, yet not constrain it so that it produces excessively narrow and short-range work.

Each company must decide, in the light of expected scientific and commercial developments, the scientific areas where it will concentrate its efforts, those where it will merely keep in touch with the scientific community, and those where it will virtually ignore developing knowledge. Top management's ultimate control over the scope, emphasis, and efficiency of research lies largely in the selection of key personnel. Research and general managers decide in what broad fields to do research, and staff the program accordingly. Within these fields, they tend to rely heavily on the judgment of researchers to select specific inquiries and particular approaches to the problem.

The management of research is presently far from a science. Numerous propositions are put forth, but few are testable and practically none has been tested in any formal way. The following six points summarize a few of the propositions in the literature, and help to illustrate the sorts of managerial problems that exist in this area. First, it is frequently stated that a company's research aims should be clearly spelled out and communicated to the scientists, and that its research should be undertaken in broad areas relevant to its economic goals. If a firm simply hires teams of scientists and allows them to do research in their favorite fields, the results may be novel and interesting, but they are unlikely to have much commercial value to the company.

Second, it is often pointed out that top management's responsibilities do not end with the definition of the objectives of research and development. Management must also make sure that its organization performs certain critical planning functions. Research and development should be responsive to technological flows from three sources: the company's competitors, the company's present and prospective customers, and the scientific community in general. Despite the difficulties in technological forecasting, the firm must attempt to forecast, as best it can, the new developments that will come from these sources.

Third, management must pay proper attention to the transfer of new technology into operations. This is sometimes an extremely difficult task. On the one hand, this transfer may be restricted because the researcher does not recognize the commercial implications of his work or does not want to release his findings until he has covered more of its scientific ramifications. On the other hand, operating groups sometimes resist new technology on the ground that it is "impractical" or because, although it is desirable in the long run, it will add to their short-run marketing or engineering costs. Various devices, such as the movement of people across the interface between R and D and other departments and the creation of new product committees and departments, have been used to help reduce the resistance to the transfer of new technology into operations.

Fourth, it is important to prevent the isolation of research from development. In a company where this is the case, the research people may be divorced from practical applications and their work may have little practical value. On the other hand, according to many observers, there are dangers if no line is drawn between research and development. The program may become dominated by short-term, product-oriented projects, and the exploration of fundamentally new areas may be neglected.

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Fifth, it is frequently pointed out that a reasonable limit should be placed on the amount of "fire-fighting" activities to be done by researchers. In most companies, management tends to value technical service to customers and to the company's manufacturing divisions as one of the most important products of its technical groups. Sometimes management feels that whenever an emergency service call comes in, longer-range R and D projects can be dropped temporarily. Too much work of this sort produces resentment among scientists and engineers, and detracts considerably from a laboratory's power to produce important new ideas in the long run.

Sixth, it is also important to recognize that the firm's R and D department is only one of many sources of new ideas. There is sometimes a tendency for R and D managers to focus too much attention on new developments arising from their laboratories, and to neglect developments in other firms and industries. If something is "not invented here," it may be neglected or resisted.

4. R and D's Returns and Effects on Productivity

For a variety of reasons, it is very difficult to make accurate forecasts of the returns from a particular R and D project. Thus, firms find it difficult to determine with precision how much they ought to spend on research and development. In the short run, they sometimes maintain a fairly constant ratio between R and D expenditures and sales. In the longer run, they adjust their desired ratio of R and D expenditures to sales in response to changes in the perceived profitability of research and development, changes in the profitability of the firm, and changes in the amount spent by their competitors.

Some tentative and experimental estimates have been made of the marginal rate of return from R and D expenditures in a variety of firms and industries. Griliches, Mansfield, Minasian, and Terleckyj have carried out studies of this sort based on the idea that R and D expenditures, as well as labor and capital, should be included as inputs in the production function. In general, the results of these studies suggest that the marginal rate of return from R and D expenditures has been relatively high. However, for reasons discussed by all of these authors, these estimates should be viewed with great caution.

In addition, econometric studies indicate that R and D has a very important effect on the rate of productivity increase in the industries and the time periods that have been studied. In one of the earliest studies of this topic, Jora Minasian found that chemical firms' rate of productivity increase was directly related to their expenditures on R and D. His results indicated that, during the period to which his data pertained, the marginal rate of return--that is, the rate of return from an additional dollar spent--was about 50 percent for R and D in chemicals. A study of my own indicated that the marginal rate of return from R and D was about 40 percent or more in the petroleum industry and about 30 percent in the chemical industry. In agriculture, Zvi Griliches found that output was related in a statistically significant way to the amount spent on research and extension. Assuming a six-year lag between research input and its returns, his results indicated a marginal rate of return from agricultural R and D of 53 percent. In the twenty years that have elapsed since these early investigations, economists have found similar results in one industry after another. (Note that many of the rates of return estimated by economists, because they are social rates of return, are likely to be higher than the private rate of return to the firm carrying out the R and D.)

5. Basic Research's Effects on Productivity Increase

Although the studies described in the previous section provide valuable information concerning the relationship between total R and D input and productivity change, they tell us nothing about the effect of the composition of an industry's or firm's R and D on its rate of productivity change. In particular, they tell us nothing about the role of basic research in promoting productivity increase. Basic research is defined by the National Science Foundation as "original investigation for the advancement of scientific knowledge . . . which [does] not have immediate commercial objectives." Does basic research, as contrasted with applied research and development, make a significant contribution to an industry's or firm's rate of technological innovation and productivity change? Although the studies cited above indicated that an industry's or firm's R and D expenditures have been directly related to its rate of productivity change, they were unable to shed light on this question because no attempt was made to separate basic research from applied research and development. About five years ago, I carried out an econometric study to determine whether an industry's or firm's rate of productivity change in recent years had been related to the amount of basic research it performed, when other relevant variables (such as its rate of expenditure on applied R and D) were held constant. This study has various limitations, but its results have been of interest, particularly since so little research has been done on this score.

The findings indicate that there was a statistically significant and direct relationship between the amount of basic research carried out by an industry or firm and its rate of increase of total factor productivity when its expenditures on applied R and D were held constant. To some extent, this may reflect a tendency for basic research findings to be exploited more fully by the industries and firms that were responsible for them. Or it may reflect a tendency for applied R and D to be more effective when carried out in conjunction with some basic research. Whether the relevant distinction is between basic and applied research is by no means clear: there is some evidence that basic research may be acting to some extent as a proxy for long-term R and D. Holding constant the amount spent on both applied R and D and basic research, an industry's rate of productivity increase seems to be directly and significantly related to the extent to which its R and D is long term. This constituted the first systematic evidence that the composition, as well as the size, of an industry's or firm's R and D expenditures affect its rate of productivity increase. However, it really is just a beginning. Much more work is required in this area, since the composition of R and D is for many purposes as important as its total amount.

Given the above findings, it is interesting to consider the changes over time in the proportion of industrial R and D expenditures devoted to basic research. Between 1967 and 1977, the proportion of R and D expenditures devoted to basic research declined in practically every industry for which we have data. In the aerospace, metals, electrical equipment, office equipment and computer, chemical, drug, and rubber industries, this proportion dropped substantially. In our sample as a whole, the proportion fell about one-fourth, from 5.6 percent in 1967 to 4.1 percent in 1977. According to data published by the National Science Foundation, this proportion increased during the 1980s, from about 4.1 percent in 1980 to 4.5 percent in 1983, but is still significantly lower than in the 1960s.

6. Conclusion

In conclusion, ideas and proposals for research projects stem from customers and from the marketing and production departments of a firm, as well as from its R and D department. To evaluate these proposals, some large firms use relatively simple extensions of the criteria--like the pay-out period and the rate of return--used in capital budgeting. When projects are first proposed, the screening is often cursory and informal, since there is considerable uncertainty regarding the results and the costs are small. However, as projects go into development, costs increase and uncertainties decrease, the consequence being that detailed economic evaluation of the project becomes both more necessary and more feasible. Many of the projects that are accepted initially are scrapped before the development stage. In the short run, there often is a tendency for firms to maintain a fairly constant ratio between R and D expenditures and sales, but in the longer run, this ratio changes in response to changes in the prospective profitability of research, bandwagon effects, and other factors.

One of the most difficult problems in this area is the measurement of the returns from research and development. There is some evidence that the number of significant inventions carried out by a firm is highly correlated with the level of its R and D expenditures. Beyond this very little is known, although a limited amount of experimental work has been carried out. Chance plays a crucial role in research and development, and a long string of failures often occurs before any sort of success is achieved. R and D can be regarded as a process of uncertainty reduction or learning. Viewed in this way, it obviously is desirable under certain circumstances to run in parallel several approaches to the same problem, the optimal number of approaches being inversely related to the prospective amount of learning. This result is important because it puts in proper perspective some of the criticisms of "duplication" and "waste" in research and development.

As stressed above, the administration and control of research and development tends to be looser and more informal than in most other areas of business. Nonetheless, top management must insure that its organization performs the critical planning functions cited above and that various devices are used to reduce the resistance to the transfer of new technology into operations. The effectiveness of an R and D department depends heavily on its relations with other parts of the firm. There sometimes are important communications difficulties, as well as problems of status and power, that separate the production and marketing people from the R and D staff. Also, there are many differences between the ideal working atmosphere of an industrial research laboratory and that of other parts of the firm. In part, these differences stem from the conflicts that may arise between the traditions and values of management, on the one hand, and of science, on the other.

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APPENDIX 2

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bcc: J. F. Schmutz, Legal
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V. R. Rice, Legal

May 1, 1985

The Honorable Donald L. Ritter
Committee on Science and Technology
U.S. House of Representatives
Rayburn House Office Building
Washington, DC 50515

Dear Congressman Ritter:

Following my testimony before the Committee on Science and Technology on April 24, 1985, you asked me what impact Superfund taxes would have on research and development activities. At the time of the question, I was not familiar with all of the Superfund taxing proposals and I told you that I would respond to the question later.

Few research and development laboratories are impacted directly by Superfund taxes since these facilities do not produce the materials taxed under Superfund. The major impact on R&D will occur through the effect Superfund taxes have on the competitiveness of the chemical industry in domestic and international markets and on company earnings. I have attached a statement given by Dr. Robert C. Forney, Executive Vice President of my Company, before the Senate Finance Committee Hearing on Superfund Reauthorization on April 26, 1985 which addresses this subject.

Dr. Forney related the support of the Chemical Manufacturers Association for a reauthorized Superfund at a level of approximately $5 billion over five years -- the amount the Administration has said could be efficiently spent. His comments focused on the following three main points:

- First, although the chemical industry overall is moderately healthy, certain sectors are in serious trouble and the world trade position of those sectors and the industry is deteriorating.
- Second, Superfund taxes impede competitiveness of sectors of the industry, particularly petrochemicals, and undercut the earnings of products on which they are imposed.
- Third, adequate Superfund revenues can be raised without unduly damaging U.S. industry.

Research and development is the life blood of the chemical industry. Through cooperative programs with the universities and government and favorable tax laws, research and development has increased over the past several years. However, industry and its research efforts are being severely strained. Additional taxes for Superfund which fall heavily on the chemical industry will decrease competitiveness and earnings and almost assuredly will slow research and development efforts. Moreover, it is inequitable for the chemical industry and the petrochemical sector in particular, to bear the major burden of increased taxes because numerous other industries have contributed in a major way to the problem sites.

It is for this reason we have advocated that the increase in funds necessary for the Superfund program be obtained through taxes which do not fall disproportionately on the chemical industry. Thus, in addition to continuation of the present feedstock taxes and cost recovery from responsible parties, we have recommended a dry weight waste end tax and increased general revenue appropriations. In the event one or more of these revenue sources is not accepted by Congress or for any other reason there is a shortfall in the mandated funding level, we have recommended a broad-based tax on manufacturers to make up the difference.

I want to thank you for the opportunity to follow up on your question.

Very truly yours,

Alexander MacLachlan
Director

AM:cmk

cc: The Honorable Donald Fuqua, Chairman
Committee on Science and Technology
U.S. House of Representatives
Rayburn House Office Building
Washington, DC 50515

WRITTEN

CHEMICAL MANUFACTURERS ASSOCIATION

STATEMENT OF

ROBERT C. FORNEY

EXECUTIVE VICE PRESIDENT

E.I. DU PONT DE NEMOURS & COMPANY

ON BEHALF OF THE

CHEMICAL MANUFACTURERS ASSOCIATION

BEFORE THE

FINANCE COMMITTEE

UNITED STATES SENATE

ON

SUPERFUND REAUTHORIZATION

APRIL 26, 1985

2501 M Street, NW • Washington, DC 20037 • Telephone 202/887-1100 • Telex 89617 (CMA WSH)

The Chemical Manufacturers Association is a non-profit trade association whose member companies represent more than 90 percent of the productive capacity for basic industrial chemicals in this country. In several appearances before congressional committees since November of 1983, we have stressed both our strong support for an effective national program to clean up problem waste sites, and our commitment to play a cooperative and constructive role in the process leading to reauthorization of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), more commonly known as Superfund.

On April 2, 1985, CMA submitted its views on Superfund reauthorization to the House Committee on Energy and Commerce. That statement, which presents this Association's views on funding and the broad scope of issues raised by the reauthorization of Superfund, is attached hereto as "Appendix A".

Our testimony will focus primarily on the funding aspects of reauthorization. Before examining the impact of CERCLA taxing mechanisms on the chemical industry, however, we would like to discuss briefly the revenue needs of the bill reported out of the Senate Environment and Public Works Committee, S. 51. In this regard, our primary concern is with the overall fund size provided for in S. 51 -- $7.5 billion over five years. As stated previously, CMA supports reauthorization of Superfund at a level of up to $1 billion per year, the amount that EPA says it can spend effectively. We do not believe that the problem of cleaning up inactive hazardous waste sites will be solved by putting more money in the Superfund program than can be used effectively.

Among the programmatic aspects of S. 51 that impact funding needs, three are of particular importance — the scope of Superfund, victims assistance programs and the provisions on health-related activities. First, we need to keep Superfund focused. Except in major emergencies, the statute should not be used to address such concerns as releases resulting from mining wastes or the lawful application of pesticides; releases from residential, business or community structures not due to hazardous waste facilities; releases of naturally occurring substances in their natural form; releases covered by and in compliance with permitted discharges, or releases of pollutants and contaminants.

S. 51 would focus more on the priority of cleanup of inactive hazardous waste sites and eliminate several of these categories from authorized Superfund response unless an emergency exists. We do not believe, however, that S. 51 goes far enough in focusing the use of Superfund resources. Instead, we commend the approach taken in the Administration's Superfund reauthorization bill, S. 464.

A second aspect of S. 51 that will divert resources from waste site cleanup is the provision for up to $30,000,000 per year for a victim assistance demonstration program. We are concerned that such a proposal could develop into an uncontrollable entitlements program that would be extremely costly for the nation.

We call to the attention of this Committee a report prepared by a scientific panel of Universities Associated for Research and Education in Pathology (UAREP). This report, the first comprehensive study of the health effects on populations around waste sites, concluded "There is little scientific evidence that chemical disposal sites have had serious effects on the health of populations living near them." UAREP nevertheless strongly urges prompt remedial action to reduce the potential for health effects. The results of the UAREP study raise fundamental doubts about the need for a new federal program to compensate persons allegedly injured by waste sites.

Now we return to the main thrust of our testimony -- the funding mechanism to be chosen for CERCLA. In testimony before this Committee last September, CMA expressed support then, and we support now, a 5 year reauthorization of Superfund at an annual funding level of up to $1 billion. To raise these revenues, CMA supports a funding mechanism that would provide for (1) continuation of the present Superfund feedstock taxes at current rates to provide $307 million per year; (2) enactment of a national tax on the disposal of hazardous waste at $50 per dry weight ton, or equivalent to produce $307 million per year; (3) support from general revenues contributions of about $175 million per year; (4) and cost recoveries and interest on unexpended fund deposits to provide just over $200 million per year. EPA projects that cost recoveries in the early years of this period will be below the $210 million level, but will build gradually to an amount in excess of $300 million per year. To provide level funding over the 5 year period, CMA proposes that EPA be given authority to borrow against amounts which will eventually be paid as cost recoveries.

We are pleased that members of this Committee and the Congress have expressed concern about the impact of increased Superfund taxes on the chemical industry. This industry is facing serious challenges from several forces, including increasing product costs, reduced sales margins, and foreign competition. Increasing the current CERCLA feedstock tax rates, as has been proposed, would produce severe, adverse economic consequences and would impose even greater competitive pressures on the industry in the international arena. Moreover, ill-advised waste-end taxes of the type included in the Administration's bill would exacerbate the undesirable effects of the feedstock tax on the chemical industry.

BACKGROUND

The chemical industry is the third largest of the manufacturing industries in the United States. It provides raw and intermediate materials that are used to make 63,000 commercial products for agriculture, business and individual consumers. It supplies products to such diverse customers as the mining, ceramics, primary metals and paper industries. The diversity of the industry is further shown by its production of synthetic rubber, fertilizers, pesticides, dyes, man-made fibers, and plastics. The industry uses as raw material and fuel about 6.7 percent of the nation's liquid petroleum consumption and over 10 percent of its natural gas consumption.

The U.S. chemical industry overall has been moderately successful in adjusting to such major challenges as the great change in energy pricing since 1973, an overvalued U.S. dollar and the high level of investment around the world in competing chemical facilities. Sales amounted to $211.3 billion in 1984, and have shown an average gain of 7.4 percent per year in the last five years. Volumes produced have gone up an average rate of 1.6 percent over the same period. The industry has increased capital expenditures about 7.4 percent per year over the last five years. Employment has declined from a peak of 1,109,000 in 1981 to 1,061,000 in 1984. The industry continues to invest in innovation as reflected by an average annual increase of 16.4 percent in spending for research and development.

TRENDS IN INTERNATIONAL CHEMICAL TRADE

However, the overall performance of the industry is clouded by the poor performance of some sectors of the industry under current world trade conditions. This is illustrated by trends in the chemical industry trade balance. The industry has typically exported a significant part of its production. But the share of sales going abroad dropped from 13.0 percent in 1980 to 10.4 percent in 1984.

The industry is losing its competitive position versus foreign products in both domestic and export markets. The contribution of the industry to the nation's trade balance is declining. The record $14 billion chemical surplus in 1981 declined 26 percent to $10.3 billion in 1984. This has serious implications for the U.S. overall trade balance which had a deficit in 1984 of $123 billion.

The most distressed sector of the chemical industry and the one particularly influenced by international competition is petrochemicals. It makes the primary basic building block or "feedstock" chemicals which are used to make derivative products (Exhibit I). The petrochemical feedstocks taxed under Superfund fall into this category. Producers of these petrochemical feedstocks are losing export and domestic markets and many are losing money on these products.

A 1982 report prepared by the U.S. Department of Commerce predicted a pessimistic future for petrochemicals.[*] The report projected a gradual decline in the competitiveness of the U.S. petrochemical industry as hydrocarbon rich countries, including the Persian Gulf states, Canada, Mexico and Indonesia, bring new capacity onstream. This new capacity will lead to a major restructuring in the worldwide petrochemical industry which, the report says, is already underway and will gain momentum in the next two decades.

The Department of Commerce's 1985 U.S. Industrial Outlook reports petrochemical shipments totalled $90.6 billion in 1984. The positive petrochemical trade balance declined from $8.6 billion in 1980 to $5.5

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[*] U.S. Department of Commerce, "A Competitive Assessment of the U.S. Petrochemical Industry" (August 31, 1982).

billion in 1984, a drop of 36 percent. At the same time, petrochemical imports have been growing at the rate of 17 percent per year since 1980. In addition, the petrochemical share of the overall chemical trade balance has declined over that same period from 62 percent to 53 percent. These and other measurements show that this segment of the industry is under severe competitive pressure throughout the world.

We emphasize that although the petrochemical industry is severely distressed, there are many operations in this industry that are capable of competing in world markets, if provided a reasonably favorable climate. The jobs and products represented by these businesses are substantial, and we should mount a great effort to preserve those that are efficient enough to compete. It is important not to further impede this industry by imposing on it domestic burdens not borne by foreign competitors.

FEEDSTOCK TAXES DAMAGE U.S. COMPETITIVENESS

Increased Superfund feedstock taxes would seriously aggravate the deteriorating condition of the U.S. petrochemical industry. In this highly competitive industry, newly imposed costs, whether raw materials, labor, construction costs, or Superfund taxes, cannot be passed through to the consumer in the export or U.S. market. Petrochemical prices are determined by competition, not by costs. Many foreign competitors selling in export markets, including the United States, are using natural gas and other feedstocks as a raw material at 1/6th the cost of that in the United States. Even allowing for higher transportation costs to export markets, U.S. producers have great difficulty in being competitive.

The petrochemical feedstocks taxed under Superfund are generally not significant in world trade. However, their downstream derivatives, which for integrated producers in the U.S. are burdened with feedstock taxes, are traded in large volumes. Ethylene is a good example. The U.S. International Trade Commission reports that ethylene production in 1983 accounted for over 13 percent of all the petrochemicals manufactured. Over the first two and one quarter years of CERCLA taxation, 40 percent of the petrochemical feedstock tax was paid on ethylene. Ethylene, however, is exported in the form of downstream products such as polyethylene resins. These products are competing against foreign products manufactured from feedstocks on which no tax is assessed.

The same factors apply in the U.S. market. It is often the feedstock derivatives that are imported, not the taxed petrochemical feedstocks. U.S. purchasers of the derivatives can buy them from either domestic or foreign producers. The U.S. producer of these downstream products finds it is, therefore, prevented from passing through the cost of feedstock taxes because of competition from untaxed foreign producers.

Recent price trends of the taxed feedstocks provide further evidence of the inability of manufacturers to pass through Superfund taxes. According to a study done for CMA by Price Waterhouse & Co., average prices for taxed petrochemical feedstocks were 25.1¢/pound in 1981, 20.1¢/pound in 1982 and 19.7¢/pound in 1983. Data from the Bureau of Labor Statistics indicate that, in 1984, this price has continued to decline to the 17-18¢/pound range. For inorganic feedstocks, the average prices were 7.6¢/pound in 1981, 7.7¢/pound in 1982 and 7.0¢/pound in 1983.

Under these conditions, even the present level of feedstock taxes undermines the competitiveness of the petrochemical sector. It is, therefore, extremely important that petrochemicals not be burdened with taxes higher than those in the present law. These taxes are cumulative with other cost factors affecting the industry's international competitiveness.

A group of 31 inorganic feedstock chemicals is also taxed by CERCLA. The trade situation for these commodities is similar to that in the petrochemical sector. The majority of these inorganic chemicals are contained in two SIC codes, (SIC 2812 and SIC 2819). Since 1980, the positive chemical trade balance for these two product sectors, including untaxed inorganic products, has dropped 31 percent from $727 million to $503 million. New taxes imposed on these products would not be passed through to customers. As in the case of petrochemicals, inorganic chemicals should not be burdened with taxes higher than those in the present law.

Feedstock taxes cannot be shifted to profitable sectors of the industry. In this nation's industrial economy, each product or group of products must be self-sustaining. Those that are not must be shut down. No company could serve well its employees or shareholders if it permitted an unprofitable line of business to reduce the overall competitiveness of the organization. The Congress is urged to consider fully the economic position of individual chemicals before imposing new costs on them.

ECONOMIC IMPACT OF SUPERFUND TAXES

In order to gain a more quantitative insight into the economic health of relevant sectors of the U.S. chemical industry and of the impact of Superfund taxes, a survey of 26 major producers of nine of the presently taxed petrochemical and inorganic feedstocks was just completed by Price Waterhouse & Co. Pre-tax earnings in the petrochemical sector were found to be negligible while those in the inorganic sector showed a significant decline.

The survey shows (Exhibit II) the distressed state of earnings for the surveyed petrochemical feedstocks and the serious downtrend of earnings for 31 inorganic feedstocks.[*] The serious condition for the petrochemicals is depicted on Exhibit III. The 1982 losses on the nine petrochemical feedstocks amounted to $91 million which increased to a loss of $188 million after estimated CERCLA taxes. Similar results with a loss of $100 million were obtained in 1983 despite an improvement in business conditions.

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[*] Price Waterhouse, "A Comparison of Sales to Earnings Ratios for Chemical Companies for Their Overall Sales and Sales of Products Subject to CERCLA Taxes" (March 15, 1985).

Pre-tax operating earnings for the 31 taxed inorganic products are somewhat better, but have declined from $415 million in 1981 to $220 million in 1983, a 47 percent decrease. The earnings to sales ratio declined from 13.4 percent in 1981 to 6.9 percent in 1982, and to 6.8 percent in 1983. This is not an acceptable rate of return. Imposition of higher Superfund taxes would only worsen this trend.

A study by DeWitt and Company, confirming the difficult situation for U.S. petrochemical producers, points out that profit margins in 1982 and 1983 were negative. [*] Much U.S. petrochemical capacity has been retired, and a substantial amount of existing capacity is in danger of being permanently shut down if new Superfund tax levels like those in H.R. 5640 last year are imposed. Thirty thousand petrochemical jobs would be lost. Another 120,000 jobs would be at stake that are dependent on petrochemical jobs. This trend is confirmed by Bureau of Labor statistics which show that 43,000 petrochemical jobs were lost in the period 1979 to 1983 and that many more are threatened by worldwide competition.

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[*] DeWitt and Company, "Superfund Economic Impact (July 17, 1984).

WASTE-END TAXES

As mentioned above, CMA has proposed a $50 per dry weight ton waste disposal tax intended to raise $307 million dollars per year. Some part of this tax must be borne by the already taxed feedstock products, and they would be disadvantaged additionally in export and domestic markets. Nevertheless, CMA has supported such a tax since it is reasonably related to the purpose for which the money is needed and, in addition, more equitably expands the base of taxpayers to other industries involved in hazardous waste sites. We believe that the Moynihan-Bentsen bill, S. 14, contains an equitable waste tax proposal. Although the tax rates are specified on a wet weight basis, an alternative dry weight computation is provided at the reasonable rate of $50 per ton.

However, some proposed waste taxes would only aggravate the inequity of the current feedstock taxes. For example, the Administration's bill, S. 494, would tax waste management rather than disposal and, in particular, would tax highly dilute waste water in certain treatment facilities. This proposed tax would raise far more money than EPA intends to raise or can reasonably spend. Even if the tax rates were revised, a tax structure which imposes a tax on dilute waste water would seriously penalize a few companies that have large waste water treatment facilities. These facilities were installed at great expense to provide environmentally sound waste management. Such a tax makes no economic or environmental sense. It would force companies, such as Du Pont, to make unproductive investments in alternative waste handling units to avoid the tax with no environmental gain whatever.

There is yet another strong reason to oppose the Administration's waste generation tax. One central justification for adopting a waste tax is to distribute the Superfund tax burden throughout the economy to all who have contributed to problem sites, rather than to concentrate that burden on two or three industry groups. Although the Superfund tax payments of many companies would be increased under the Administration's proposal, a disproportionate burden of the total Superfund taxes would continue to fall on the chemical industry because of its heavy reliance on waste water treatment facilities.

CMA, thus, strongly opposes the Administration's effort to tax waste water as highly inequitable and exacerbating the effect on trade of existing feedstock taxes.

NEED FOR GENERAL REVENUES

As stated above, CMA's proposed funding mechanism includes a general revenue component of about $175 million per year. We believe that a substantial general revenue contribution is appropriate for reasons of equity and sound public policy. The chemical industry's contribution to the Superfund far exceeds our contribution to problem waste sites. This inequity will worsen if general revenues are not provided.

The problems associated with inactive hazardous waste sites reflect more than 100 years of industrial development in the nation. Hazardous wastes have been, and will continue to be, generated by a wide range of industries, business concerns, government agencies and defense installations, municipalities and scientific facilities. The problem is societal in scope and the mechanisms for coping with it should reflect this fact, just as the benefits of resolving the problems will inure to all elements of the country. As Congress recognized when it enacted Superfund in 1980, only through the use of general revenues, both state and federal, can this societal responsibility be fairly discharged.

The Treasury has already acknowledged that broadening the Superfund tax base is best achieved by continuing substantial general revenue contributions as a part of the Superfund funding mechanism. Testifying before this Committee last September, Mikel Rollyson, Tax Legislative Counsel of the Treasury Department, stated in answer to the questions of Senator Bentsen:

> Mr. ROLLYSON.
>
> * * *
>
> "But I think to respond to your point, and also to respond to our concerns about the administrability of the tax, if the committee is interested in looking at a significantly broadening of the base for this tax, which I think is one of the principal concerns.

Senator BENTSEN. You have heard it around this table.

Mr. ROLLYSON. Then I think that broadening is better obtained by, in effect, larger appropriations from general revenues.

* * *

So I would suggest that if you are interested in a great expansion or broadening of the base for the tax, that you would consider seriously looking hard at larger shares of general revenues."

Hearings on Superfund Issues,
Senate Commitees on Finance, 98th
Congress, Second Session, September
19 and 21, 1984, page 85.

BROAD BASED TAXES

CMA believes that the chemical industry should not bear either feedstock or waste-end taxes beyond those levels recommended above. Therefore, to the extent that the items described above - feedstock and waste-end taxes, general revenues, cost recovery and interest - do not yield a fund of the size eventually authorized by Congress, CMA supports a broad-based tax - one which taxes a substantial part of U.S. industry at a low rate - to make up the difference.

CMA has been working closely with the American Petroleum Institute (API) and the staffs of several Senators to develop the concept of a broad-based invoice-type transaction tax for Superfund which we call the Manufacturer's Environmental Excise Tax ("MEET"). CMA agrees with API that "MEET" would be an acceptable broad-based tax to our member companies. But our approval of "MEET" should not preclude the consideration of other alternatives that would satisfy our basic criteria of a broad-based tax.

CMA believes that any broad-based tax to finance the Superfund program should be tested under the following basic criteria:

- Revenue Potential

  The proposed tax should provide predictable and adequate levels of revenues to finance the cleanup of problem waste sites.

- Equity

  The tax must be very broadly-based. EPA identification of responsible parties at National Priority List (NPL) waste sites has demonstrated that numerous industries, and over four thousand companies, have contributed waste to these problem sites. Fairness dictates that all these industries should also contribute to the cleanup of these sites through their tax payments.

- Trade and Economic Impact

  Any proposed tax should have a neutral or minimal impact on trade. The tax should not apply to exports. It should apply to imports or be imposed at such a low rate that it does not disadvantage domestic manufacturers with respect to imported products.

- Avoidance of Repetitive Taxation of Same Transaction

  The proposed tax should avoid any repetitive taxation of the same transaction ("cascading of tax payments").

- Environmental Nexus

  Any proposed tax should have at least some environmental nexus with the problem waste sites for which the tax is required. Since a wide spectrum of manufactured products appears at problem waste sites, a tax that would apply broadly to manufacturing would supply the requisite environmental nexus

- Administrative Feasibility, Cost And Number of Taxpayers Affected

  The proposed tax should be simple and inexpensive to administer and to collect. We believe that a tax which applies to all manufacturers would not impose an undue administrative burden.

We submit that these are the basic criteria by which any proposed broad-based tax should be judged. Several members of this Committee have introduced bills to establish a broad base funding mechanism for the re-authorization of Superfund. These include Senator Bradley (S.

596), Senators Mitchell and Chaffee (S. 955), and Senators Bentsen and Wallop (S. 957). We view the introduction of these bills as a positive development for several reasons: First, these bills reflect a growing congressional recognition that the Superfund site cleanup problem is a societal one and not merely a specific responsibility of the chemical and petroleum companies alone.

Second, these bills also reflect the recognition that the current badly depressed petrochemical industry should not pay increased taxes of the level needed to fund the Superfund site cleanup program for the next 5 years. Senator Bradley and Senator Bentsen would continue the present feedstock taxes at existing levels for an additional 5 years. Unfortunately, however, Senators Mitchell and Chafee in S. 955 would amend the feedstock taxes to raise an additional $100 million, which we oppose.

Third, all the bills recognize the need to develop a waste-end tax to raise a reasonable amount of revenue - $300 million per year. CMA believes that the waste disposal tax that is proposed in the Moynihan-Bentsen bill, S. 14, (which was adopted by Senator Bradley) at the rate of $50 per dry weight ton or equivalent is a workable tax at a reasonable rate which achieves some broadening of the tax base. In contrast, the waste generation tax as proposed in the Mitchell-Chaffee bill shares some of the faults of the Administration's bill. It is a wet weight tax and applies to some treatment facilities. As such, it is environmentally unsound and falls disproportionately on the chemical industry.

Fourth, all emphasize the need to continue Federal general revenue contributions to the Superfund trust fund.

Fifth, all would provide a broad-based tax as a third funding component for the Superfund cleanup program. CMA appreciates the great difficulty in developing an appropriate broad based tax alternative for Superfund. We believe, however, that judged by the criteria we have set forth above, the broad-based tax developed by Senator Bentsen and Senator Wallop in S. 957 is preferable to those provided in S. 596 and S. 955.

The Bentsen-Wallop bill would provide a simple, broad-based transaction tax at low rates. Since the tax applies to all manufacturers, it has the required environmental nexus. Moreover, the proposed tax is relatively trade neutral and free of "cascading" problems. CMA believes that S. 957 represents an excellent foundation for this Committee to develop a broad-based tax for Superfund.

ORAL

STATEMENT

OF

ROBERT C. FORNEY

EXECUTIVE VICE PRESIDENT

E. I. DU PONT DE NEMOURS AND COMPANY

BEFORE THE

COMMITTEE ON FINANCE

U.S. SENATE

APRIL 26, 1985

Mr. Chairman, members of the committee:

My name is Robert Forney. I am an executive vice president of the Du Pont Company, and I am representing the Chemical Manufacturers Association on whose Board of Directors I serve. While my written testimony addresses some other issues related to Superfund, my remarks this morning will focus on mechanisms for financing Superfund and have three main points:

- First, although the chemical industry overall is moderately healthy, certain sectors are in serious trouble and the world trade position of those sectors and the industry is deteriorating.
- Second, Superfund taxes impede competitiveness of sectors of the industry, particularly petrochemicals, and undercut the earnings of products on which they are imposed.
- Third, adequate Superfund revenues can be raised without unduly damaging U.S. industry; recommendations are made for your consideration.

To amplify the first point, the chemical industry has been subjected to more than a decade of price swings, market dislocations and uncertain supply conditions for its vital petroleum and hydrocarbon feedstocks. In recent years, the overvalued dollar has made exports difficult and added greatly to import competition.

Another factor with which we have had to contend is the rise of petrochemical industries in countries with vast hydrocarbon resources at a time when there is worldwide overcapacity in many basic chemical lines.

Overall, the U.S. chemical industry has managed to cope by investing in research and in process and product improvements. But the industry's international position is eroding. While our positive contribution to the balance of trade still shows a surplus of more than $10 billion, it is down by more than one-fourth from the record high in 1981.

With this background, let me turn to the second point -- the impact of Superfund taxes.

The most distressed sector of the industry is petrochemicals. Petrochemical manufacturers produce the 11 primary petrochemical building block chemicals taxed under Superfund, as well as a large number of derivative products.

Products of the U.S. petrochemical industry by and large compete in world markets with foreign products that do not bear the feedstock tax. The feedstock taxes cannot be passed along in the prices of U.S. products because customers here and abroad would simply turn to foreign suppliers of the same products.

The inability to reflect the tax in prices means that it is reflected in the earnings of this already extremely distressed sector. Losses in 1982 on the nine major petrochemical feedstocks amounted to $91 million which increased to a loss of $188 million after CERCLA taxes. Despite improved business in 1983, the loss came to $100 million.

Finally, as I stated to your committee last year, CMA supports a reauthorized Superfund at a level of approximately $5 billion over five years -- the amount the Administration has said could be efficiently spent. We believe the financing should come from annual additions to the fund of $307 million in current feedstock taxes, $307 million in a dry-weight tax on hazardous waste disposed, $210 million in cost recoveries and interest and $176 million in general revenues.

The money from general revenues would recognize that hazardous wastes at problem sites have been generated by a range of business, government and scientific facilities.

Raising part of the funds from a waste-end tax would be more equitable than higher feedstock taxes.

We submit, however, that some waste-end tax proposals -- including the Administration bill -- have serious faults. They would tax waste generation instead of waste disposal, and they would tax wet weight instead of dry weight. This would have a number of adverse consequences, the worst of which is that there would be a tax on highly dilute wastewater. This would not only be unfair, it would make no environmental sense. These wastewater treatment facilities were built at great expense to provide environmentally sound waste management.

If Superfund revenues should fall short because of failure to approve the plan outlined or because of a mandated increase in the fund beyond the amount the Administration says can be efficiently used, we would support a broad-based tax to make up the difference. Such a tax would spread responsibility for Superfund more broadly among those companies and industries which have contributed to the problem.

We are pleased that broad-based tax proposals have been introduced by Senator Bradley, by Senators Mitchell and Chafee, and by Senators Bentsen and Wallop. Measured against the several criteria the CMA has developed for a broad-based tax, the Bentsen-Wallop proposal, which is a transaction type tax on manufactured products, appears to be closest to what we would suggest. We are confident that an acceptable proposal can be developed.

We appreciate the opportunity to testify. I am available for any questions you may have.

# # # # #

4/26/85

EXHIBIT I

FLOW CHART - PETROCHEMICAL SOURCES TO END-USE APPLICATIONS

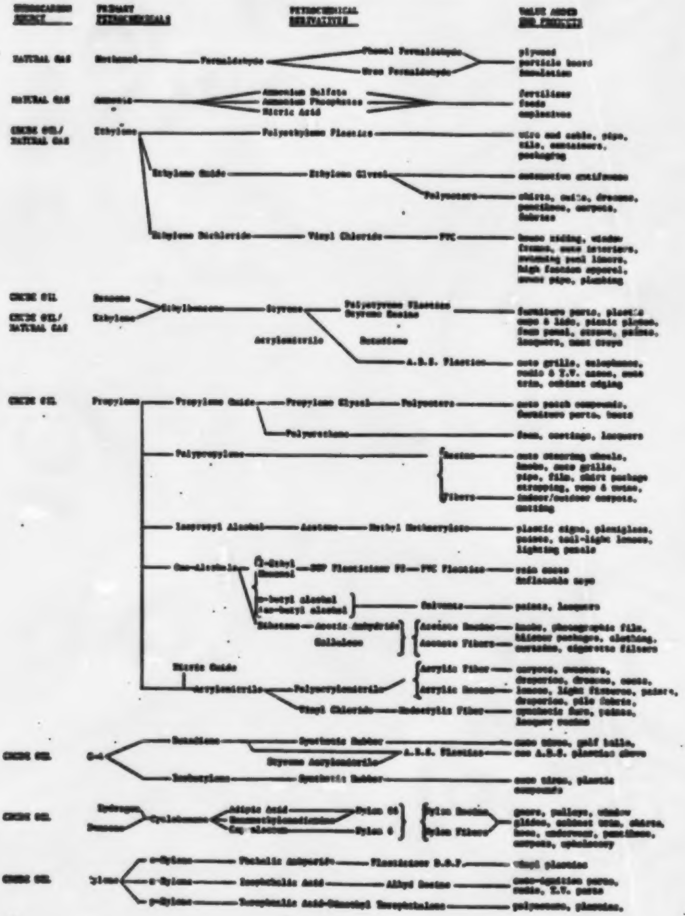

HYDROCARBON SOURCE
PRIMARY PETROCHEMICALS
PETROCHEMICAL DERIVATIVES
VALUE ADDED END PRODUCTS
NATURAL GAS
Methanol
Formaldehyde
Phenol Formaldehyde
Urea Formaldehyde
plywood
particle board
insulation
NATURAL GAS
Ammonia
Ammonium Sulfate
Ammonium Phosphates
Nitric Acid
fertilizer
feeds
explosives
CRUDE OIL/ NATURAL GAS
Ethylene
Polyethylene Plastics
wire and cable, pipe, film, containers, packaging
Ethylene Oxide
Ethylene Glycol
automotive antifreeze
Polyesters
shirts, suits, dresses, panties, carpets, fabrics
Ethylene Dichloride
Vinyl Chloride
PVC
house siding, window frames, auto interiors, swimming pool liners, high fashion apparel, sewer pipe, plumbing
CRUDE OIL
Benzene
CRUDE OIL/ NATURAL GAS
Ethylene
Ethylbenzene
Styrene
Polystyrene Plastics
Styrene Resins
Acrylonitrile
Butadiene
A.B.S. Plastics
furniture parts, plastic cups & lids, picnic plates, foam panel, cases, paints, lacquers, meat trays
auto grills, telephones, radio & T.V. cases, auto trim, cabinet edging
CRUDE OIL
Propylene
Propylene Oxide
Propylene Glycol
Polyesters
auto patch compounds, furniture parts, boats
Polyurethane
foam, coatings, lacquers
Polypropylene
Resins
Fibers
auto steering wheels, knobs, auto grills, pipe, film, shirt package strapping, rope & twine, indoor/outdoor carpets, netting
Isopropyl Alcohol
Acetone
Methyl Methacrylate
plastic signs, plexiglass, paints, tail-light lenses, lighting panels
Oxo-alcohols
2-Ethyl Hexanol
DOP Plasticizer
PVC Plastics
rain coats
inflatable toys
n-butyl alcohol
iso-butyl alcohol
Solvents
paints, lacquers
Ketene
Acetic Anhydride
Cellulose
Acetate Resins
Acetate Fibers
knobs, photographic film, blister packages, clothing, curtains, cigarette filters
Nitric Oxide
Acrylonitrile
Polyacrylonitrile
Acrylic Fiber
Acrylic Resins
Vinyl Chloride
Modacrylic Fiber
carpets, sweaters, draperies, dresses, coats, lenses, light fixtures, paints, draperies, pile fabric, synthetic furs, paints, lacquer coatings
CRUDE OIL
C-4
Butadiene
Synthetic Rubber
Styrene Acrylonitrile
A.B.S. Plastics
auto tires, golf balls,
see A.B.S. plastics above
Isobutylene
Synthetic Rubber
auto tires, plastic compounds
CRUDE OIL
Hydrogen
Benzene
Cyclohexane
Adipic Acid
Hexamethylenediamine
Cap. alcohol
Nylon 66
Nylon 6
Nylon Resins
Nylon Fibers
gears, pulleys, window glides, cabinet trim, shirts, hose, underwear, panties, carpets, upholstery
CRUDE OIL
Xylene
o-Xylene
Phthalic Anhydride
Plasticizer D.O.P.
vinyl plastics
m-Xylene
Isophthalic Acid
Alkyd Resins
auto-ignition parts, radio, T.V. parts
p-Xylene
Terephthalic Acid-Dimethyl Terephthalate
polyesters, plastics,

EXHIBIT 2

A Comparison of Earnings to Sales Ratios of Chemical Companies for Their Overall Chemical Sales and Sales of Products Subject to CERCLA Taxes

	1981		1982		1983	
	Pre-tax Earnings[3] (mil $)	Chemical Sales (mil $)	Pre-tax Earnings[3] (mil $)	Chemical Sales (mil $)	Pre-tax Earnings[3] (mil $)	Chemical Sales (mil $)
Overall Chemical Sales[1] (Chemical & Engineering News)	6038	82365	2386	72138	4418	73725
Earnings to sales ratio (%)	7.33		3.30		5.99	
Petrochemical sales subject[2] to CERCLA taxes	722	8649	-91	8011	14	9194
Earnings to sales ratio (%)	8.35		-1.14		0.15	
Inorganic chemical sales subject[2] to CERCLA taxes	415	3094	227	3297	220	3214
Earnings to sales ratio (%)	13.42		6.89		6.85	

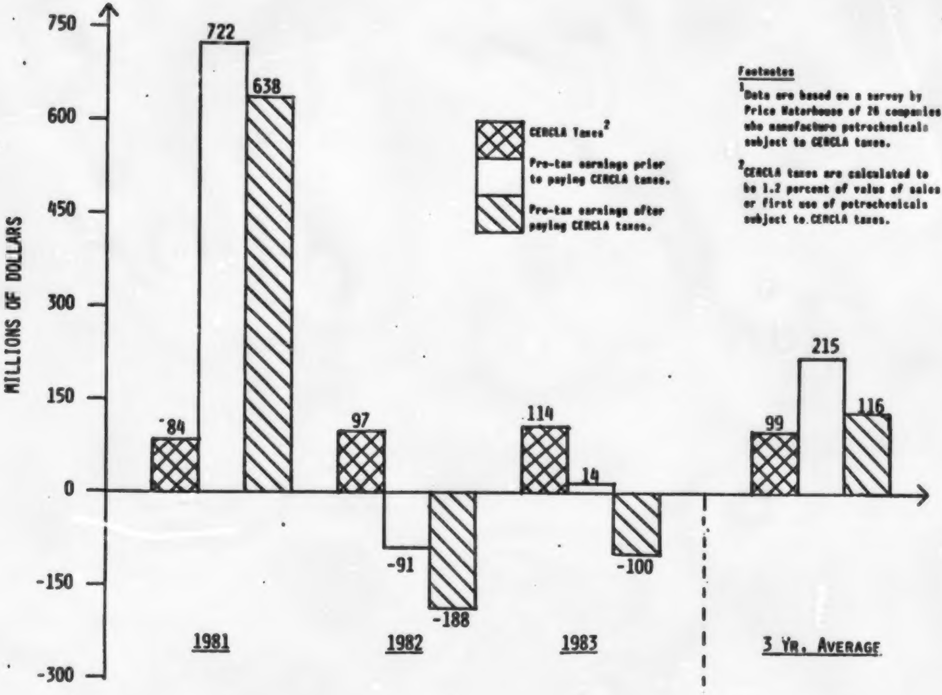
NOTE: [1] Overall chemical sales are total chemical sales for the 26 companies who responded to a CMA survey conducted by Price Waterhouse & Company as reported by Chemical & Engineering News, June 11, 1984. The companies were selected because of their large volume of production of products subject to CERCLA tax.

[2] Sales and earnings data are totals of the 26 companies responding to the CMA survey.

[3] Prior to CERCLA tax

EXHIBIT 3

THE EFFECT ON PRE-TAX EARNINGS ON PETROCHEMICAL FEEDSTOCKS SUBJECT TO CERCLA TAXES[1]

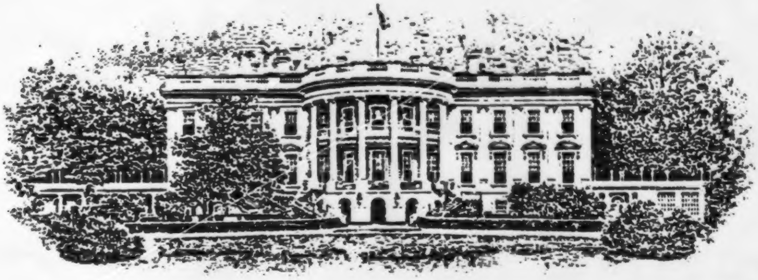


Footnotes

[1] Data are based on a survey by Price Waterhouse of 26 companies who manufacture petrochemicals subject to CERCLA taxes.

[2] CERCLA taxes are calculated to be 1.2 percent of value of sales or first use of petrochemicals subject to CERCLA taxes.

APPENDIX 3



PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL

TASK FORCE REPORT ON RESEARCH AND DEVELOPMENT

SUBMITTED TO THE SUBCOMMITTEE FOR
CONSIDERATION AT ITS MEETING ON DECEMBER 8, 1983

PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL

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RESEARCH AND DEVELOPMENT

SUBMITTED TO THE SUBCOMMITTEE FOR CONSIDERATION
AT ITS MEETING ON DECEMBER 8, 1983

THE PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL

October, 1983

Mr. J. Peter Grace
Chairman
Executive Committee
President's Private Sector Survey
  on Cost Control
1730 Pennsylvania Ave., N.W.
Washington, D.C. 20006

Dear Mr. Grace:

This is the Report of the President's Private Sector Survey on Cost Control Task Force on Research and Development (R&D) in the Federal Government. The Task Force's mission was to review the operations and management of major R&D agencies throughout the Government, including the Department of Defense, Department of Energy, Department of Health and Human Services, National Aeronautics and Space Administration, and National Science Foundation, as well as to identify opportunities for improvement. These five agencies account for over 93 percent of all Federal R&D expenditures.

This Report represents the combined efforts of 31 corporate executives with 483 years of private sector experience, 51 years of public sector experience, and eight years of academic experience. In developing this Report, we attempted to identify lessons learned in R&D management in the private sector and to apply those which appeared to fit the Government R&D process.

The Report contains 122 proposed major recommendations which, when fully implemented, could result in first-year cost savings and revenue generation of $10.9 billion and three-year cost savings and revenue generation of $45.1 billion. Of the 122 proposed recommendations, 97 were covered in other Task Force reports and, when implemented, would generate $33.0 billion in cost savings and revenue. The 25 recommendations formulated in the issues contained in this Report could generate three-year cost savings opportunities of $12.1 billion when implemented. Of these recommendations 18, or 72 percent, can be implemented through existing agency authority.

1730 Pennsylvania Avenue • Suite 450 • Washington, D.C. 20006
(202) 466-5170

Mr. J. P. Grace
Chairman
October, 1983
Page 2

The work of our Task Force has represented an enormous challenge and resulted in a tremendous feeling of accomplishment. We thank you for the opportunity of working with you on this important project.

Sincerely,

William F. Ballhaus
President
Beckman Instruments, Inc.

David Packard
Chairman
Hewlett-Packard Co.

Karl D. Bays
Chairman and CEO
American Hospital Supply Corp.

Edson W. Spencer
Chairman and CEO
Honeywell, Inc.

James L. Ferguson
Chairman and CEO
General Foods Corp.

PRESIDENT'S PRIVATE SECTOR SURVEY ON COST CONTROL

TASK FORCE REPORT ON
RESEARCH AND DEVELOPMENT

SUBMITTED TO THE SUBCOMMITTEE FOR CONSIDERATION
AT ITS MEETING ON DECEMBER 8, 1983

PREFACE

On June 30, 1982, President Reagan signed Executive Order 12369 formally establishing the President's Private Sector Survey on Cost Control (PPSSCC) in the Executive Branch of the Federal Government. An Executive Committee under the chairmanship of J. Peter Grace was established, consisting of 161 high-level private sector executives--mostly chairmen and chief executive officers--from many of the nation's leading corporations.

Briefly stated, the President directed the PPSSCC to:

- o Identify opportunities for increased efficiency and reduced costs achievable by executive action or legislation.
- o Determine areas where managerial accountability can be enhanced and administrative controls improved.
- o Suggest short- and long-term managerial operating improvements.
- o Specify areas where further study can be justified by potential savings.
- o Provide information and data relating to governmental expenditures, indebtedness, and personnel management.

The Executive Order also provided that "the Committee is to be funded, staffed and equipped . . . by the private sector without cost to the Federal Government." To implement this objective, the Foundation for the President's Private Sector Survey on Cost Control was established. It formed a Management Office which organized thirty-six "Task Forces," each co-chaired by two or more members of the Executive Committee, to do the "preliminary reports." These are listed below:

Agriculture
Air Force
Army
Automated Data Processing/Office Automation
Boards/Commissions-Banking
Boards/Commissions-Business Related
Commerce
Defense-Office of Secretary
Education
Energy (including Federal Energy Regulatory Commission and Nuclear Regulatory Commission)
Environmental Protection Agency/Small Business Administration/Federal Emergency Management Agency
Federal Construction Management
Federal Feeding
Federal Hospital Management
Federal Management Systems
Financial Asset Management
Health & Human Services-Department Management/Human Development Services/ACTION
Health & Human Services-Public Health Service/Health Care Financing Admin.
Health & Human Services-Social Security Administration
Housing & Urban Development
Interior
Justice
Labor
Land, Facilities and Personal Property Management
Low Income Standards and Benefits
Navy
Personnel Management
Privatization
Procurement/Contracts/Inventory Management
Real Property Management
Research and Development (National Science Foundation/National Aeronautics & Space Admin.)
State/AID/USIA
Transportation
Treasury
User Charges
Veterans Administration
Management Office Selected Issues

Twenty-two of these task forces were assigned to study specific departments and agencies, and the remaining fourteen studied functions cutting across government such as personnel, data processing and procurement. Apart from the co-chairpersons, none of the task force members were members of the Executive Committee, nor did the task forces have any authority to make recommendations to departments and agencies or to the President.

Each of the 36 task forces prepared a draft report. This is one such task force report. Each, with a few exceptions, also prepared an appendix providing more detailed information supporting the tentative recommendations contained in the task force report. Those appendices are on file at the Department of Commerce's Central Reference and Records Inspection Facility. It should be noted that tentative recommendations relating to any one federal agency may be included not only in the appropriate agency task force report but also in the reports of the functional cross-cutting task forces.

All of the task force draft reports will be considered and acted upon in meetings open to the public by a Subcommittee of the Executive Committee of PPSSCC, along with other statements and recommendations. Accordingly, all tentative recommendations contained in this task force report are subject to possible changes resulting from the Subcommittee's deliberations. In addition, in identifying the implementation authority for each recommendation, the Task Force drew upon all available data at its disposal. Because of the complexities of the appropriations process, as well as historical precedents, further data could result in a change in the PPSS-identified authority.

It is important to note that cost savings, revenue generation, and cash acceleration opportunities in this draft report may duplicate similar dollar opportunities reported in other task force reports. Thus, there may be instances of double counting of dollar opportunities between task force reports. These duplications will be netted-out in the Final Summary Report to the President. Additionally, dollar estimates in this draft report are based on reasonable and defensible assumptions, including standard three-year projections based on first, second, and third year partial or full implementation will occur. Accordingly, estimated savings or revenue opportunities are understandably of a "planning" quality and not of a "budget" quality. Therefore, the reader should guard against drawing conclusions or making dollar projections based on the disclosures contained only in this draft report.

Following action upon all of the task force reports, the Executive Committee will adopt a Final Summary Report to the President, summarizing the scope of its individual task force recommendations and offering general conclusions and advice.

TABLE OF CONTENTS

	Page Number
EXECUTIVE SUMMARY	i
THE REPORT RECOMMENDATIONS -- A PERSPECTIVE	vi
I. INTRODUCTION	1
II. ISSUE AND RECOMMENDATION SUMMARIES	
R&D 1: Strategic Planning	14
R&D 2: R&D Management and the Budget Process	38
R&D 3: Privatization	59
R&D 4: Improved Management of Resources in Federal Research Laboratories	67
R&D 5: Administration of Research Grants to Universities	81
R&D 6: Research Program Reporting	103
R&D 7: NASA Cost Reporting	113
R&D 8: Compendium of Selected R&D Issues	118
III. SUMMARY LIST OF RECOMMENDATIONS AND SAVINGS	127
IV. COST CONTROL OPPORTUNITIES FOR FURTHER STUDY	130
V. R&D TASK FORCE MEMBERSHIP	147

TABLE OF EXHIBITS

Exhibit	Title	Page Number
I-1	Intersectoral Transfers of Funds Used for Performance of Research and Development, 1982	2
I-2	Total R&D Budget; Percent Distribution	4
I-3	Federally Funded R&D by Performer, FY 1983	6
I-4	Federal Obligations for Basic and Applied Research by Category, FY 1983	7
I-5	DOD R&D Budget by Service; Percent Distribution	8
II-1	Strategic Planning	15
II-2	Summary Table: Five Federal Goals Compared to Basic Industry Criteria for Establishing Effective Goals	24
II-3	FY 1983 Budget Process	40
II-4	FY 1983 R&D Federal Budget Detail	43
II-5	Congressional Staff Size 1947-1980 (Personal and Committee Staff)	46
II-6	Congressional Staff Size (R&D Oversight Committees)	47
II-7	Federal Employment Compared to Congressional Staff Size	49
II-8	Relative Percentage of Scientists and Engineers Employed in R&D by Sector; Nature of R&D by Sector	68
II-9	Number of Federal Research Labs and Percent of Total Operating Costs; Percent of Total Research Lab Operating Costs, by Agency	75
II-10	Trends in Total Federal R&D Budgets and Federally Supported University Research	83
II-11	Source of R&D Funding and Type of R&D Performed at Universities	84

TABLE OF EXHIBITS (CONT'D)

Exhibit	Title	Page Number
II-12	Federal Obligations for Research & Development to the 100 Universities and Colleges Receiving the Largest Amounts, by Agency: FY 1980	85
II-13	Distribution of University R&D Support Among Major Federal Agencies	89
II-14	Differences Resulting from NSF's Redefinition of Grant Procedures	96
II-15	R&D Issues Covered in Other Reports	120
IV-1	Institutions Having the Greatest Number of Publications in Coal Gasification	140
IV-2	Sony Corp. Technology (Patent Activity) Profile for Years 1971 to 1980 Using U.S. Patent Office Classification System	142
IV-3	Number of Scientific Papers Produced by Federal Laboratories	143
IV-4	Quantitative Comparison of Two Multi-Disciplinary Programs	145

Table	Title	Page Number
II-1	History of Indirect Cost Rates Paid by NIH	92
II-2	Trends in Average Amount Awarded for NIH Traditional Research Project Grants: Fiscal Years 1970-1982 in Terms of 1970 Dollars	94
II-3	Federal Obligations for Research in the Physical and Environmental Sciences by Agency and Detailed Field of Science: FY 1983	104
II-4	National Marine Pollution Program Funding by Agency and Categories in FY 1981	108

TABLE OF EXHIBITS (CONT'D)

Figure	Title	Page Number
II-1	DOD (Army) Organization Chart	51
II-2	$2 Billion Industrial R&D Firm	52

EXECUTIVE SUMMARY

FEDERAL RESEARCH AND DEVELOPMENT

REPORT PROFILE:

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Dr. William F. Ballhaus
President
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Karl D. Bays
Chairman and CEO
American Hospital Supply Corp.

James L. Ferguson
Chairman and CEO
General Food Corp.

David Packard
Chairman
Hewlett-Packard Co.

Edson W. Spencer
Chairman and CEO
Honeywell, Inc.

PROJECT MANAGER:

Dr. Eugene E. Yore
Corporate Director
Honeywell, Inc.

NUMBER OF TASK FORCE MEMBERS: 31

NUMBER OF ISSUES: 8
RECOMMENDATIONS: 122

THREE-YEAR FULLY/ PARTIALLY SUPPORTED, COST SAVINGS/REVENUE GENERATION:
($ millions) $45,074.0

(Note: This Report contains a compendium issue covering R&D issues from other reports. It includes 97 recommendations with three-year cost savings/ revenue generation of $32,984.2 million.)

RESEARCH AND DEVELOPMENT OVERVIEW

Research and development (R&D) in the Federal Government is conducted primarily by five agencies which together account for 93.2 percent of the total FY 1983 R&D budget of $44.3 billion. These agencies are the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), Department of Energy (DOE), Department of Health and Human Services (HHS), and National Science Foundation (NSF). The R&D funded by these agencies is conducted by industrial firms (52 percent), Government laboratories (24 percent), universities (11 percent), Federally funded research and development centers (9 percent), and others (4 percent). There are over 700 laboratories employing more than 206,000 personnel which conduct the 24 percent of the R&D performed in-house.

OVERALL PERSPECTIVE

The Task Force was favorably impressed with the high quality of R&D managers in the Federal Government -- the

Presidential appointees, senior executives and R&D civil servants. They are skilled and work very hard at R&D management. Open and cooperative attitudes with interest in improvement were prevalent. Yet within this overall environment, some very important problems were found and a great deal of room for improvement was identified. Specifically, the Task Force identified the need for agency top management to become much more actively involved in establishing the specific goals for R&D in terms which are clear, precise, and measurable. Also, this lack of direction to substantive aspects of R&D and a budget process which severely inhibits the management process combine to create a system which cannot establish program priorities and which results in a great deal of program instability.

ISSUES AND RECOMMENDATIONS

The Task Force selected eight issue areas to survey and formulated recommendations which, when fully implemented, could result in three-year cost savings and revenue generation opportunities of $45.1 billion. One of the eight is a compendium of R&D issues from 14 other task force reports. This compendium issue incorporates 97 recommendations with $33 billion in three-year cost savings and revenue generation opportunities. In the other seven issue areas surveyed, the Task Force formulated 25 recommendations which, when implemented, could result in three-year savings opportunities of $12.1 billion.

It should be noted, however, that some of the recommendations may require several years for the savings and revenue to be realized. While all facets of R&D management could not be surveyed in the time allotted, areas selected for review were considered to offer significant potential for cost control and improved efficiency. The importance of the accompanying recommendations rest on the fact that they represent the potential for better utilizing finite resources available to the Federal Government.

Strategic Planning -- R&D management suffers from a lack of clearly defined goals. Existing planning efforts do not establish priorities for R&D programs, cannot eliminate marginal programs, and do not serve as a base for operational management. Most existing plans are compendiums of pet projects derived from lower levels in the organization and do not reflect a coherent approach to meeting specified goals within the constraints of available resources. Specific Task Force recommendations to alleviate the above findings would result in three-year cost savings of $7,300 million. These recommendations include:

- focusing efforts by top management on the development of clear, measurable statements of R&D goals in their respective agencies;
- developing systems necessary to translate the goal statements into complete plans; and
- committing to the use of the strategic plans to guide the operations of each agency.

R&D management and the Budget Process -- The budget process used to obtain funding for the R&D programs is too cumbersome and time consuming. The three-year budget planning period is a factor in the significant cost growth experienced in R&D programs. For example, presenting an R&D budget for DOD, NASA and DOE in terms of 1,822 individual projects creates tremendous burdens on the agencies and creates a situation which invites micromanagement. To remedy these deficiencies, the Task Force recommends the following actions, which would account for $3,670 million in savings opportunities over three years:

- Implement multiyear budgeting specifically for R&D activities.
- Use a budget activity structure that significantly reduces the current level of detail required for R&D programs.
- Shorten the budget cycle.
- Reduce technical staff positions in R&D agencies.

Privatization -- In its review of R&D activities, the Task Force was aware that there were several opportunities to privatize Federal R&D efforts. Other task forces suggested private funding for the fifth shuttle, privatizing the National Fertilizer Development Center, and getting DOD labs out of advanced development work on weapon systems. The DOE Task Force recommended that the Government cease funding activities that do not fit within the framework of Federal responsibilities for R&D, including the Clinch River Breeder Reactor. In the view of the Task Force, a concentrated analysis of privatization opportunities would result in the identification of billions of dollars in potential savings.

Management of Federal R&D Laboratories -- All R&D literature cites the "over 700 Federal R&D labs," which are an integral part of the Government R&D program. This Task Force found that 90 percent of the operating costs are used by the 146 labs with more than 100 employees. The other

600 "labs" are small facilities, two-thirds of which have fewer than 25 employees. In reviewing some of the major labs, the Task Force found some with outdated facilities and equipment, all with personnel problems, and no formal system for evaluating the laboratories' contribution to the agency's program(s). The Task Force makes seven recommendations to improve the labs' performance, including greater use of "centers of excellence," a concept which concentrates research resources to achieve a critical mass in selected areas. Savings opportunities of $506.4 million over three years were identified.

Administration of Research Grants to Universities -- An increasing percentage of the money going to universities to conduct research for the Federal Government is used to cover the indirect costs of the research. The largest elements of these indirect costs are the three administrative components (departmental administration, general and administration, and sponsored project administration). Past efforts to negotiate an approach to handling these cost elements have not been entirely successful and have resulted in a system which is a major burden to the universities and a major area of contention between the two parties. The Task Force recommends that the Government and the universities negotiate a fixed rate beneficial to both parties to reimburse these costs. Because of the reduced burden this would place on the universities and because of a fixed limit on this element, the Task Force estimates savings opportunities of $387.9 million over a three-year period.

Research Program Reporting -- The Task Force found that current efforts at reporting ongoing research efforts were incomplete and that the system which processes the data, the National Technical Information Service, did not have the tools to expand the reporting. Three-year savings opportunities of $225 million would occur if:

- use of the data base were made mandatory, and
- requirements were implemented to ensure research performers supplied the information.

NASA Cost Reporting -- Space project cost data reported by NASA was found to be significantly understated since NASA does not include Civil Service and other essential cost elements in its reporting. Recommendations have been made for over ten years to expand the project management and reporting systems to cover these costs. The Task Force believes that NASA's reasons for these omissions are inadequate and recommends that all project costs be managed and reported in the same system. No specific savings opportunities were identified with this management improvement recommendation.

IMPLEMENTATION

Of the 25 major recommendations formulated by the Task Force, 18 (72 percent) are entirely within the purview of the Executive Branch and 7 (28 percent) will need Congressional approval. (Implementation authority for the 97 recommendations covered by the compendium issue is included in the individual Task Force reports.) All of the recommendations dealing with strategic planning can be implemented within Executive Branch authority. Because of the nature of the recommendations dealing with R&D management and the budget process, Congressional approval will be required. Most of the other recommendations can be implemented within the Executive Branch.

SUMMARY

The Task Force's recommendations focus on overall management rather than its detail. Economic benefits associated with those recommendations are believed to be a conservative evaluation of what the nation might gain if Federal R&D management assumed a more businesslike approach. If all of the people involved concentrate their efforts on overcoming the problems that have been identified, other benefits, whose value is hard to quantify but which surely must be measured in additional billions, will accrue to the American economy and society.

THE REPORT RECOMMENDATIONS -- A PERSPECTIVE

As the product of an unprecedented and wide-ranging survey performed in a political atmosphere by private sector executives and specialists, the recommendations in this Task Force report must be placed in perspective. Our volunteer staff had the formidable task of bringing its expertise to bear on complex Federal operations in the short span of a few months while holding down other full- or part-time employment.

Despite these challenges -- most of which were anticipated at the outset -- valuable analysis and issue development were achieved. The recommendations contained in this report will result, if implemented, in real and significant savings and other benefits to American taxpayers whose hard work and personal sacrifices financially support these Federal programs and operations.

We believe that the majority of our recommendations are fully substantiated. However, it would be misleading to allege that each and every recommendation is rooted in a uniformly high level of research, analysis and substantiation. Various time limitations, business resources, and other constraints did not permit achievement of the desired uniformity objective.

We have evaluated, therefore, the "supportability" of the recommendations on their management merits and have grouped them into the following three categories.

- Category I -- Fully substantiated and defensible. Recommendations in this category are, in the opinion of the Task Force, convincing and deserving of prompt implementation.

- Category II -- Substantially documented and supportable. Recommendations in this category may not be fully rationalized or documented in the report, but all indications point to the desirability and defensibility of proceeding with their implementation.

- Category III -- *Potentially justifiable and supportable*. Recommendations in this category, while meritorious, are not regarded as fully supported in the report, due to time, personnel resources, and other constraints, but are deemed worthy of further analysis to determine the full extent of their merit.

These category descriptions do not take into account political, social or economic conditions which may alter the supportability of these recommendations for implementation. Accordingly, it is possible, by grouping the recommendations along the above categories, to assess more effectively the cost savings that can be expected. This analysis permits summary estimates of firm, probable and potential savings.

The Report Recommendations -- An Assessment

Based on the above perspective and categorization, an assessment of the reported recommendations is contained in the matrix on the following page.

Three-Year Cost Savings (S)/Revenue (R)/
Cash Acceleration (CA) Opportunities 1/
($ millions)

Issue/Recommendations		Category I	Category II	Category III
R&D 1	Strategic Planning	$ 7,300.0 (S)		
R&D 2	R&D Management and the Budget Process	3,670.0 (S)		
R&D 3	Privatization	2/		
R&D 4	Management of Federal R&D Laboratories	506.4 (S)		
R&D 5	Administration of Research Grants to Universities	387.9 (S)		
R&D 6	Research Program Reporting	225.5 (S)		
R&D 7	NASA Cost Reporting	2/		
R&D 8	Compendium Issue	23,518.5 (S)	9,399.3 (S) 66.4 (R)	
	Total Savings (S) by Category	$35,608.3 (S)	$9,399.3 (S)	$ --
	Total Revenue (R) by Category	$ --	$ 66.4 (R)	$ --
	Grand Total Savings and Revenue	$35,608.3	$9,465.7	$ --

1/ Amounts in this summary cover three years, include inflation, and are net of implementation costs.

2/ Recommendation not quantified.

I. INTRODUCTION

Federal Research and Development

Total research and development (R&D) in the United States is approaching the $80 billion level. As shown in Exhibit I-1, the funding level in 1982 was $77.3 billion with $74.6 billion coming from industry and Government in almost equal proportions (industry-funded, 49.8 percent; Government-funded, 46.7 percent). A substantial amount of the Government funding of R&D is transferred to industry ($17.8 billion) and universities ($6.95 billion) for the actual conduct of the R&D. Thus, while industry funded an estimated 49.8 percent of the national R&D effort in 1982, it performed 72.1 percent of the total R&D. Government, in contrast, funded 46.7 percent of the 1982 effort, but only performed 12.9 percent.

Federal Government efforts in R&D have three broad objectives:

- to perform R&D for the Government's own use, i.e., to achieve the mission of the various Federal agencies;
- to provide a strong science and technology base for the nation, its development and educational programs; and
- to expedite commercial exploitation of technology and ensure a strong economy.

The Federal Government has two major responsibilities with respect to meeting national needs through R&D:

- to provide a climate for technological innovation that encourages private sector R&D investment, and
- to focus R&D support on areas with significant potential benefit to the nation, but where the private sector is unlikely to invest adequately.

[Exhibit I-1 on the following page]

Exhibit I-1

Intersectoral Transfers of Funds Used for Performance of Research and Development, 1982 (est., millions of dollars)

Sources of funds	Performers Federal Government	Industry	Universities & Colleges*	Other nonprofits	Total	% distribution, sources
Federal Government	10,000	17,800	6,950	1,375	36,125	46.7
Industry		37,900	275	325	38,500	49.8
Universities & colleges			1,600		1,600	2.1
Other non-profits			475	585	1,060	1.4
Total	10,000	55,700	9,300	2,285	77,285	100.0
% distribution, performers	12.9	72.1	12.0	3.0	100.0	

---

* Includes university-affiliated, Federally Funded Research and Development Centers (FFRDCs).

SOURCE: National Science Foundation: "National Patterns of Science and Technology Indicators," 1982.

The Federal Government will spend approximately $44.3 billion for the conduct of R&D in FY 1983. 1/ Exhibit I-2, on the following page, shows the breakdown of that amount by principal agencies. The Department of Defense (DOD) accounted for more than half (56 percent) of the Government funding for R&D. The National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) account for another 25.7 percent. The remainder of the R&D budget (18.3 percent) comes from the Department of Health and Human Services (HHS), the National Science Foundation (NSF), and the other agencies.

The Office of Science and Technology Policy (OSTP), established within the Executive Office of the President in 1976, is involved in overall Government R&D. This Office had a budget in FY 1983 of $1.84 million and 12 full-time permanent positions. OSTP's responsibilities include:

- advising the President on science and technology considerations related to the economy, national security, foreign relations, health, energy, environment, resources and other related matters;
- evaluating the Federal effort in science and technology and recommending appropriate action on it;
- advising the President on science and technology considerations in the Federal budget and working with the Office of Management and Budget (OMB) on the review and analysis of R&D items in the budgets of all Federal agencies; and
- assisting the President in coordinating the R&D programs of the Federal Government.

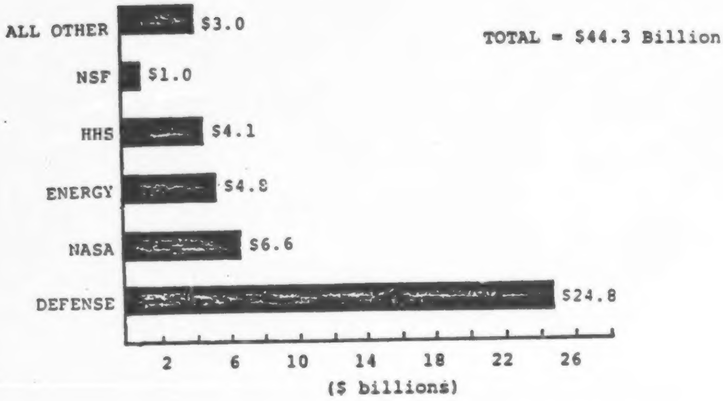
As such it is primarily involved in macro-policy matters and does not, in general, get actively involved in the direction of the individual R&D programs. Its primary concerns focus on the supply of engineering and scientific manpower to support technology development; cooperation between the basic research efforts of the Government, universities and industry; and the basic thrusts of overall science and technology efforts.

[Exhibit I-2 on the following page]

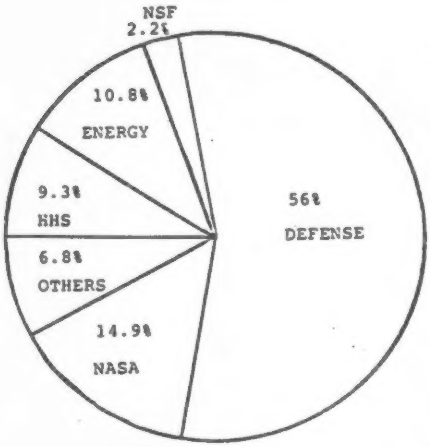
1/ The estimate of $44.3 billion for Federal R&D is derived from the official FY 198 budget documents. This figure differs with the figure shown in Exhibit I-1 ($36,125 million), which came from an NSF publication (NSF Report 82-319). Although the discrepancies cannot be fully reconciled, they are probably due to definitional and reporting inconsistencies.

Exhibit I-2

TOTAL R&D BUDGET



% DISTRIBUTION



SOURCE: Office of Management and Budget, FY 1983 Budget.

The Government has more than 700 R&D laboratories under its auspices, employing more than 206,000 people. However, only 23.7 percent of all Federally funded R&D is conducted intramurally (within Government-owned and -operated laboratories). About 52 percent of Federally funded R&D is conducted by industrial firms. An additional 3.3 percent is conducted by industrial firms at Federally Funded Research and Development Centers. The remainder is performed by nonprofit institutions such as universities, by state and local governments, and by foreign researchers. Exhibit I-3, on the following page, presents the distribution of Federally funded R&D by performer.

Federal Government involvement in R&D spans the spectrum of scientific and social disciplines. Exhibit I-4 presents a breakdown of the Federal budget by basic and applied research categories. Research in the life sciences (e.g., biology) will receive more than $4.7 billion, or 35.7 percent of the total estimated budget of $13.3 billion for basic and applied research in FY 1983. About $3.2 billion, or 23.9 percent, will be spent for engineering research; research in the physical sciences (e.g., physics) will account for $2.8 billion, or 21.5 percent of the total budget. 2/

The following is a more detailed overview of each of the principal agencies expending R&D funds:

Department of Defense -- R&D funds for DOD are used to support the modernization of the national defense forces through the development of new strategic and tactical weapons and supporting systems. 3/ Nearly $25 billion (56 percent) of the total Federal R&D budget is obligated for Defense R&D (including test and evaluation) in FY 1983, representing a 19 percent increase over FY 1982. Funds are apportioned among DOD's three Services (Army, Air Force and Navy), nonaffiliated defense research agencies, and the director of test and evaluation. Approximately 46 percent ($11.4 billion) of Defense R&D is conducted or sponsored by the Air Force. Exhibit I-5 presents a breakdown of the Defense R&D budget by Service.

[Exhibits I-3, I-4 and I-5 on the following pages]

2/ National Science Foundation, Federal Funds for Research Development, Fiscal Years 1981, 1982 and 1983.

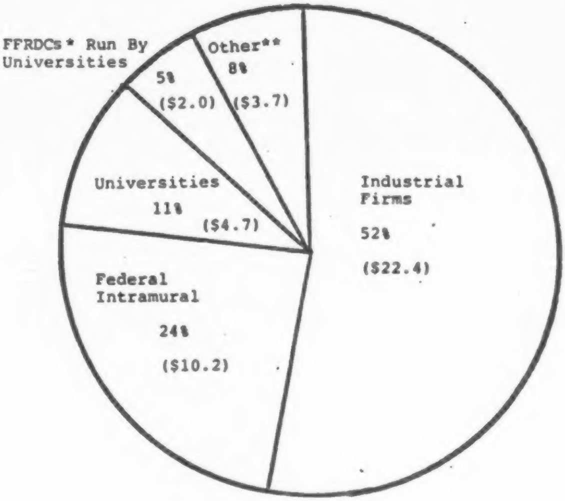
3/ President's Budget, FY 1984, Appendix.

Exhibit I-3

FEDERALLY FUNDED R&D BY PERFORMER, FY 1983 (estimated)

($ billions)

Total = $43.0, Excluding
$1.3 for R&D
Facilities



Source: National Science Foundation, Federal Funds for Research and Development, Fiscal Years 1981, 1982 and 1983.

*Federally Funded Research and Development Centers (FFRDCs)

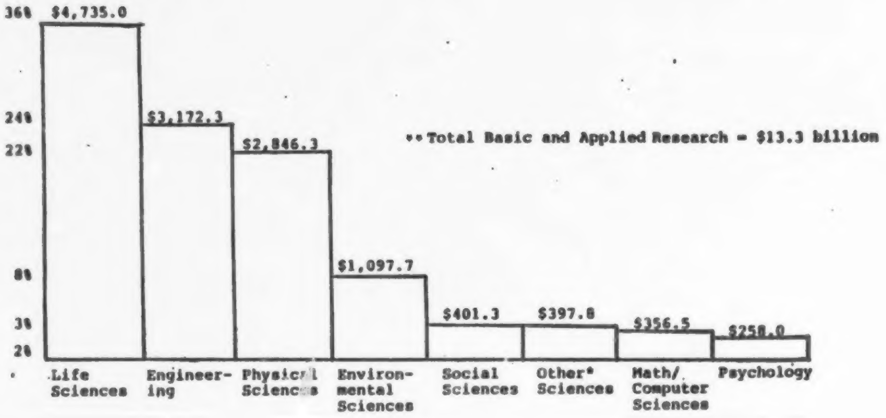
**Other:

FFRDCS Run by Industrial Firms	3.0%	($1.4)
Other Non-Profit Institutions	3.0%	($1.2)
FFRDCS Run by Non-Profit Institutions	1.0%	($0.6)
Foreign Governments	0.6%	($0.3)
State and Local Governments	0.4%	($0.2)

Exhibit I-4

FEDERAL OBLIGATIONS FOR BASIC AND APPLIED RESEARCH BY CATEGORY, FY 1983 (estimated)

($ millions)



SOURCE: Op. Cit., National Science Foundation

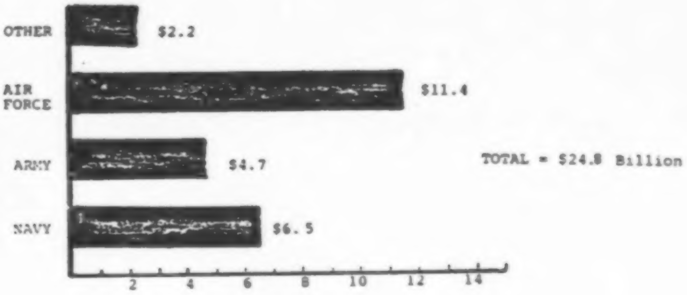
*Not Elsewhere Classified

**Excludes $30 billion for development and R&D facilities

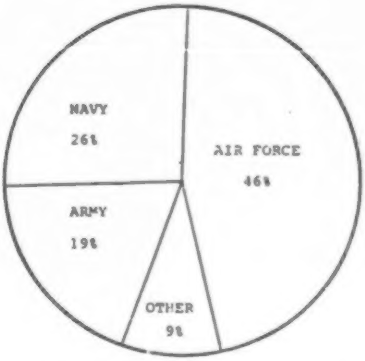
254

Exhibit I-5

DOD FY 1983 R&D BUDGET BY SERVICE
($ billions)



% DISTRIBUTION



SOURCE: Office of Management and Budget, FY 1983 Budget.

Defense R&D program areas and FY 1983 budget obligations are as follows:

	($ millions)
Technology Base	$ 3,288
Advance Technology Development	928
Strategic Programs	6,520
Tactical Programs	7,524
Intelligence and Communications	2,675
Program Management and Support	2,849
Other Appropriations	685
R&D Facilities	366
Total obligations	$24,835

The R&D expenditures of DOD, in addition to providing for the defense of the country, have many impacts in the private sector. The work on the very high speed integrated circuits (VHSIC), which is included in several of these R&D categories, will have direct impacts on civilian technology products. In the past, the Government-funded B-52 R&D was in part responsible for the commercial Boeing 707 airplane.

National Aeronautics and Space Administration -- Government investment in R&D through NASA has the objective of yielding new space technologies to improve the long-term scientific and technological strength of the nation. Over $6.6 billion, or 14.9 percent of the Federal R&D budget, is obligated for FY 1983 to meet that objective. This represents about an 11 percent increase over FY 1982 obligations. Over 52 percent of NASA's R&D budget will go to the Space Transportation Systems (STS) program. The main components of that program are the development, testing and procurement of the Space Shuttle fleet and continued procurement of the second Space-lab. STS and other NASA R&D programs are funded as follows:

	($ millions)
Program	1983 Estimate
Space transportation system	$ 3,468
Space science	682
Space and terrestrial applications	320
Aeronautical research and technology	232
Space research and technology	123
Energy technology	---
Tracking and data acquisition	509
Research and program management	1,179
Total conduct of R&D	$ 6,513
R&D facilities	116
Total obligations	$ 6,629

Department of Energy -- DOE R&D has the objectives of (a) developing new energy technologies, (b) improving existing technologies, and (c) developing a better understanding of high energy physics and nuclear sciences. About $4.8 billion, or 10.8 percent of the total Federal R&D budget, will go toward achieving these objectives. This includes $220 million for R&D sponsored by the Nuclear Regulatory Commission. 4/

Health and Human Services -- R&D funding for HHS in FY 1983 is projected at $4.1 billion, or 9.3 percent of the Federal R&D budget. This represents about a 3 percent increase over FY 1982 obligations. Over 85 percent of HHS R&D funds are obligated by the National Institutes of Health (NIH), which conducts R&D in the following areas:

- life processes in health and disease,
- clinical research,
- antiviral drugs,
- diabetes,
- epidemiology, and
- toxicology.

FY 1983 obligations by HHS major R&D activities are as follows:

Health:	($ millions)
National Institutes of Health	$ 3,533
Alcohol, Drug Abuse and Mental Health Administration	289
Food and Drug Administration	75
Centers for Disease Control	74
Health Care Financing Administration	30
Office of Assistant Secretary for Health	20
Health Services Administration	1
Special Foreign Currency Program	1
Subtotal	$ 4,023

4/ DOE R&D functions were proposed for transfer to the Department of Commerce (DOC) under the name of the Energy Research and Technology Administration (ERTA). This has not yet occurred. Therefore, DOE R&D figures in this Report include those attributed to the Department of Commerce, ERTA, in budget literature for FY 1983.

Human Services:

Office of Human Development Services	$ 59
Social Security Administration	25
Departmental Management	16
Subtotal	$ 100
Total conduct of R&D	$4,123
R&D facilities	$ 20
Total obligations	$4,143

National Science Foundation -- NSF's share of the FY 1983 R&D budget is $1.0 billion, or 2.2 percent of the total R&D budget, which represents a 7.5 percent increase over FY 1982.

NSF obligations are primarily used to support basic research in all scientific disciplines through grants to scientists and engineers associated with academic institutions. The NSF R&D objective is to complement basic research programs of agencies such as DOD and NIH.

Task Force Methodology

During its review of the Federal R&D process, the Task Force addressed seven major issues:

- Strategic Planning,
- R&D Management and Budget Process,
- Privatization,
- Management of Federal R&D Laboratories,
- Administration of Research Grants to Universities,
- Research Program Reporting, and
- NASA Cost Reporting.

These issues were selected for study because:

- They represent the largest potential cost savings of all issues surfaced.

- They require the highest level support to obtain resolution.
- They are fundamental or underlying causes of many problems identified but not resolved by past studies.

In addition to these seven issues, the Task Force prepared a compendium of R&D issues included in the other PPSS Task Force reports.

The nature and extent of the problems related to R&D management were substantiated during personal interviews with Presidential appointees and other key agency management personnel. Further information was gained by interviewing officials from OMB, the General Accounting Office, OSTP, and other selected sources.

A literature review of prior reports and past studies on the issue was also conducted. In all, 414 personal contacts were made and 104 significant past studies examined.

In reviewing Federal Government R&D, we contacted the major agencies including DOD, NASA, DOE, HHS (including NIH), NSF, Department of Agriculture, DOC, Department of Transportation, and the Environmental Protection Agency. Individual issues used the results of the data collected from subsets of these agencies. They are identified in the methodology sections of the appropriate issue.

Significant Contributions

We acknowledge the significant contributions of the Co-chairmen of the R&D Task Force: William Ballhaus (Beckman Instruments); Karl Bays (American Hospital Supply); James Ferguson (General Foods); David Packard (Hewlett-Packard); and Edson Spencer (Honeywell). These individuals devoted a good deal of time and personal attention to reviewing and guiding the study. We also acknowledge the significant contributions of the R&D Task Force members on temporary assignment in Washington, D.C. Our PPSS Management Field Officer O.T. Berkman and Desk Officer

Robert Pikul contributed thoughtful and helpful guidance. We had exceptional administrative support under the supervision of Linda Holt.

A number of persons in the various agencies were contacted and interviewed in the course of the Task Force's assessment of Federal R&D. The area of expertise and the perspective of those interviewed varied widely, as would be expected, but the spirit of cooperation and openness was universal and outstanding. Agency officials and staff provided data and supporting documentation that greatly assisted our efforts. Their attitude and support were critical to the success of the PPSS effort.

We specifically thank NASA for providing office space conducive to the Task Force work and NSF for assistance in gathering statistical data, references, and other information.

We would also like to acknowledge the time and contributions of private sector persons who helped validate our own private sector administrative model. We have listed these contributions in Section V.

II. ISSUE AND RECOMMENDATION SUMMARIES

RESEARCH AND DEVELOPMENT

R&D 1: STRATEGIC PLANNING

Issue and Savings

Can improvements in strategic planning, particularly in the goal-setting process, result in improved and more cost-effective research and development (R&D) management in the agencies?

The Task Force believes that significant improvements are possible in the R&D management process through the implementation of effective strategic planning. Implementation of specific recommendations would result in estimated savings of $2.2 billion in the first year, $2.4 billion in the second year, and $2.7 billion in the third year for total three-year savings of $7.3 billion.

Background

Strategic planning has evolved over the last 25 years into a valuable management tool, one that is necessary to set the overall direction for any organization and to provide the framework to guide both long-range and short-term actions. As shown in Exhibit II-1, on the following page, it is basically a system to:

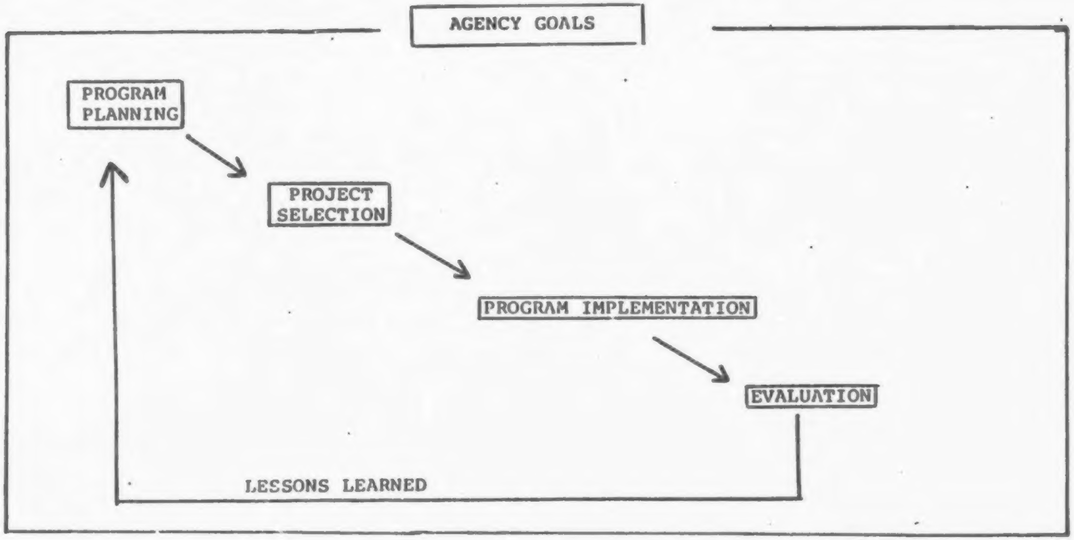
- o articulate the agency goals;
- o formulate and evaluate program plans for achieving the goals;
- o select alternative projects within resource constraints;
- o prepare and document implementation actions; and
- o evaluate the programs.

Strategic planning must be evaluated as a process and as a substantive activity, particularly in the statement of goals. If the goals that come out of the process do not contain the necessary attributes, then the remainder of the

[Exhibit II-1 on the following page]

Exhibit II-1

STRATEGIC PLANNING


AGENCY GOALS
PROGRAM PLANNING
PROJECT SELECTION
PROGRAM IMPLEMENTATION
EVALUATION
LESSONS LEARNED

steps in the process of strategic planning are of limited value. It is increasingly recognized that the establishment of goals is one of the most difficult tasks involved in strategic planning. It is also apparent that in those situations where the goals were poorly defined, the results of the entire process were less than satisfactory.

In recent years, the private sector has increasingly emphasized and focused attention on the establishment of specific long-range goals. More and more large corporations are instituting formal long-range strategic planning processes. Most corporations start by analyzing economic conditions and their projected market posture for ten or 15 years into the future. This exercise helps executives set specific goals and establish program definitions, budgets, and schedules, emphasizing the required near-term actions. These plans are usually produced by an iterative process involving many management levels, then communicated to all managers and supervisors. Top management reviews the plans periodically and must concur in any changes. The plans are used to establish and maintain audit trails for progress evaluations.

The Task Force members are familiar with the R&D strategic planning processes used by the corporations represented on the Task Force and other well-managed industrial firms. Benefits of strategic planning must be very real because major corporations have continued to increase their planning emphasis, despite the many implementation problems that have been identified.

Within the Government, strategic planning received its first real emphasis in the early 1960s with the efforts of Secretary McNamara in the Department of Defense (DOD). Initial strategic planning efforts were made under the Planning, Programming and Budgeting System (PPBS). Since then, the name of the systems and the emphasis have changed, but some of the elements of the strategic planning process are in place in most agencies. The elements currently used include:

- definition of goals (sometimes called missions or objectives);
- analysis of requirements and constraints;
- identification of alternatives;
- analysis of alternatives;

- comparison of alternative to resources;
- selection of alternative;
- definition of implementing actions;
- consolidation and review; and
- documentation.

This issue will address both the key substantive point of strategic planning (the definition of goals) and the process of strategic planning.

Methodology

The following approach was taken to develop the findings and validate the conclusions reached. The Task Force:

- determined current agency practices by review of the literature, assessment of current practices, and interviews with senior agency management;
- analyzed previous studies in related areas and discussed them with agency management; and
- assessed comparable industry practices and experience.

Prior to discussions with Federal agencies regarding strategic planning techniques, Task Force personnel performed a review of business publications on the subject, compared techniques used by major industrial firms, and reviewed prior studies performed on planning problems for the technology base within several Federal agencies.

Since it would have taken many months of effort on the part of this team to review all agencies with R&D budgets, the Task Force decided to concentrate its efforts for this issue on three Federal agencies: DOD, the National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE). These three agencies are presently budgeted for $36.2 billion, which represents 82 percent of the total FY 1983 R&D budget. Further, as DOD spends 56 percent of these funds, the Task Force emphasized its R&D involvement. We did, however, briefly consider the National Institutes of Health (NIH) and the Department of Agriculture (USDA).

Although the team's efforts were concentrated on the three agencies, there is every reason to believe that the findings are typical of all agencies. Any benefits that could be derived from implementation of recommendations contained in this Report could be similarly achieved by the other agencies.

Findings

Based on the experience in our own corporations and on knowledge of other corporations in the private sector, the Task Force believes that the Government is five to ten years behind industry in strategic planning. There appears to be limited long-range strategic planning in Government agencies. Although a number of agencies have partially developed elements of the strategic planning process, none of these elements are based on specific Federal goals.

In describing our findings on strategic planning in the principal R&D agencies in the Federal Government, we have made a distinction between the statements of goals used in the planning process and the process itself. In some cases, strategic planning is based on goal statements that are so broad and general that they minimize the benefits that can be derived from the process. In other cases, where goals have been well defined, strategic planning can be a valuable tool.

Our analysis of strategic planning starts with an assessment of the existing statements of goals. This is then followed by an assessment of the strategic planning process itself. The section concludes with several findings dealing with the results of existing planning processes.

1. Lack of Consensus on Goals

The absence of full agreement on Federal goals causes confusion within the agencies and forces them to create their own goals. This is the greatest problem the Task Force found in current strategic planning efforts.

DOD serves as a clear illustration. The three Services (Army, Navy, and Air Force) plan almost autonomously and frequently at cross purposes with little direction provided by the Under Secretary of Defense for Research and Engineering (USDRE) or the Office of the Secretary of Defense (OSD). There are relatively few joint programs between the Services, even though their tactical requirements often demand essentially the same R&D. In NASA and DOE, the absence of Federal goals has led to disarray in setting priorities and to "bootlegging" pet projects.

In order to be more specific about the problems with existing Federal goals, the Task Force put together a set of criteria to be used in evaluating the usefulness of goals for strategic planning purposes. In developing these criteria, the Task Force relied on the experience in their own corporations and the general literature available.

- A good goal is a clear, measurable, specific statement of what is to be accomplished (for example, "reduce the nation's infant mortality rate by two percent over the next five years").
- A time frame is stated ("improve communications and control systems in the next eight years to make sure we can communicate with strategic forces, even after a nuclear attack").
- The group responsible for implementation is designated ("to be carried out by the Chief of Naval Operations").
- Projected results of achieving the goal are perceived by the public, by employees and by others to be worthwhile (e.g., successful completion of a magnetic fusion demonstration plan would provide the nation with a safe, renewable, inexpensive source of energy).
- The goal is feasible (e.g., "put a man on the moon by the end of the decade").

If goals do not meet these criteria, then there will be little or no guidance in the design of alternatives; their analysis, ranking and selection; and the identification of implementing actions. A goal for NIH to "reduce the nation's infant mortality rate by 2 percent over the next five years" provides real guidance and direction to strategic planning. In contrast, a goal to "solve the nations's energy problems" provides little, if any, help to the subsequent steps.

Using the criteria defined above, the Task Force analyzed the content of some of the more prominent Federal goals.

Strategic Program for Defense -- The Strategic Program for Defense provides an example of a goal developed in extensive consultation between the White House and DOD, and then articulated by the President. It is a comprehensive plan for revitalizing our strategic deterrent which will end the relative decline of U.S. strategic capabilities and put the

United States in a position to reshape the U.S.-Soviet strategic competition in the eight years ahead. It deals with one specific area of national defense and embodies all of the basic characteristics of an effective goal. It outlines in detail in which direction the President wants to lead the nation in five strategic areas. It specifies a time frame for achieving results. The responsible party is clearly DOD. Further, it is perceived to be worthwhile in enhancing the defense posture of the United States. It is feasible and can be accomplished in the time period specified. It is acceptable to DOD, Congress, and the public.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
Strategic Program for Defense	Yes	Yes	Yes	Yes	Yes

National Space Policy -- The R&D goals of NASA are to extend our knowledge of the earth, its space environment and the universe; to expand space technology for practical applications; to develop, operate, and improve manned and unmanned space vehicles; to provide technology for improving the performance of aeronautical vehicles; and to assure continued development of the aeronautics and space technology necessary to accomplish national goals. These national goals articulated by President Reagan are:

- to strengthen the security of the United States;
- to maintain United States space leadership;
- to obtain economic and scientific benefits through the exploitation of space;
- to expand United States private sector investment and involvement in civilian space and space-related activities;
- to promote international cooperative activities in the national interest; and

- to cooperate with other nations in order to maintain the freedom of space for activities which enhance the security and welfare of mankind.

NASA's mission statement is too general to be considered much more than public relations, and the President's space policy is not much more specific.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
National Space Policy	No	No	Yes	Maybe	Maybe

NASA's goal is incomplete compared to the five industry attributes of a well-articulated goal. Goal ambiguity forces NASA to fill in the gaps on its own. As a result, the agency's planning process suffers from the lack of top-down guidance.

National Heart, Lung and Blood Institute (NHLBI) -- The mission of NHLBI, "... to advance the national attack against diseases of the heart and blood vessels, the lungs and blood ..." also does not meet the industry criteria.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
NHLBI	No	No	Yes	Yes	Maybe

The issue team recognizes that setting specific goals for basic research is more difficult than for applied research. Efforts should be made to be as specific as possible, but strict adherence to demands of timing or feasibility may be unrealistic. Again, nebulous goals are hampering a good planning process.

Energy -- National goals for energy development are in shambles. This is understandable in light of:

- oil embargoes and instability in the Middle East;

- the distinct lack of public confidence in nuclear energy, prompted by the Three Mile Island crisis and the nuclear waste disposal question;
- DOE's tentative future;
- the shift in policy to allow the marketplace to guide the development of energy systems; and
- public disillusionment with expenditures on alternative energy technologies, i.e., their failure to provide commercially viable energy production systems.

The issue team believes this is a prime example of an area where it is difficult to develop meaningful goals; by the same token, it is urgent that specific energy goals be developed.

The Task Force reviewed two statements of goals in the energy area: The National Energy Policy Plan and the much more specific Magnetic Fusion Energy Program. The National Energy Policy Plan, submitted by President Reagan to Congress to meet the requirements of the Department of Energy Organization Act (PL 95-91), is a broad statement of the Administration's energy policy. The issue team did not find adequate guidance in the 1981 statement (the latest available at this time) for DOE management. As a broad policy document it did not articulate clear, measurable and specific goals which were to be met in a stated time frame.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
National Energy Policy Plan	No	No	Yes	Yes	No

In contrast, The Magnetic Fusion Energy Engineering Act of 1980 (P.L. 96-386) provides national goals for demonstrating the scientific and engineering feasibility of the use of fusion energy. By industry standards, this is a fairly complete goal.

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worthwhile	Feasible Goal
Magnetic Energy Fusion Program	Yes	Yes	Yes	Yes	Maybe

Some experts, however, question the scientific and commercial feasibility of this goal.

Summary -- In setting goals, an effort must be made to prevent political considerations and "wishful thinking" from biasing or overriding technical analysis. This may or may not have happened in the energy goal-setting process. There will always be some doubt about a goal's feasibility. The issue team emphasizes this doubt because it is commonly voiced during any good goal-setting process. Decision-makers worry that despite good analysis, the goal cannot be met. There is no way to avoid the doubt. Therefore, goal-setting must be an ongoing process, where progress and feasibility are constantly reevaluated.

The issue team found elements at work in each of the agencies, but none has a complete set (see Exhibit II-2, Summary Table, on the following page). The clarity and content of the actual goals simply do not meet the industry standard. There is little evidence of top-down, bottom-up consultation combined with staff analysis. None of the agencies has a complete set of clearly defined Federal goals. The absence of goals severely hampers the ability of existing planning processes to produce results. Typically, the agencies attempt to cover as many areas as possible rather than targeting R&D to top national priorities. This approach tends to allow R&D projects to proliferate when many of them should be terminated. All of the PPSS Task Force reports dealing with weapon systems development and procurement (OSD, Air Force, Navy and Procurement) found, for example, that DOD suffers from an inability to prioritize its weapon systems projects.

[Exhibit II-2 on following page]

EXHIBIT II-2

SUMMARY TABLE: Five Federal Goals Compared to Basic Industry Criteria For Establishing Effective Goals

	Clear Measurable Specific	Stated Time Frame	Responsible Group Designated	Results Worth-while	Feasible Goal
Strategic Program for Defense	Yes	Yes	Yes	Yes	Yes
National Space Policy	No	No	Yes	Maybe	Maybe
NHLBI	No	No	Yes	Yes	Maybe
National Energy Policy Plan	No	No	Yes	Yes	No
Magnetic Fusion Energy	Yes	Yes	Yes	Yes	Maybe

2. Most Agencies Use Key Elements of the Strategic Planning Process

Most of the Federal agencies utilize some of the key elements of strategic planning. In some cases, they do not receive the emphasis they should because they are dominated by the annual budget process. In other cases, their effectiveness is severely hampered by the inadequacies in the goal statements cited above. The following paragraphs briefly evaluate the process used in the major agencies.

Department of Defense (DOD) -- At present overall DOD planning as well as R&D strategic planning is highly fragmented. Each Service has developed its own independent planning techniques, and each essentially competes for budget funding. Very few joint programs are underway, and the role of USDRE is minimal due to the fact that it has no authority for overall R&D programs within the Services, other than veto power. It would be difficult to establish a strategic plan for DOD R&D unless either OSD or USDRE directly manages the three Services, as well as other agencies within DOD such as the Defense Advanced Research Project Agency (DARPA). At present, the three Services operate very different R&D planning processes, as described below.

- Air Force -- The Air Force has developed and is using a formal planning process called Vanguard. It requires that each planner identify the jobs that must be done and assess the Air Force capabilities to perform those jobs with current forces and currently programmed improvements. The planning system is designed to identify potential deficiencies, planned modifications, and comparison with budget constraints. The Vanguard plans are prepared as briefings. When properly used, the plan will provide answers to such questions as: (a) How does a program element contribute to meeting Air Force military needs? (b) What is the contribution of a program to other mission areas? (c) What is the effect of cancellation or delay? (d) Does it fit the budget? (e) What are the key decision points and when do they occur? (f) Is the new system compatible with existing programs?

  A technology plan links basic research and exploratory development programs to decisions provided by other plans, thus providing guidance to the laboratories. The Vanguard planning process is in its early stages of implementation and has not been in place long enough to produce any notable improvements.

There is little or no coordination of programs among the other Services of OSD included in this planning process. One of the purposes of the Vanguard plan is to project needs of the Air Force for the next 15 years. Accordingly, the plan should encompass joint efforts among the Services and be integrated with their long-range planning documents. For example, the Army Air Land 2000 and the Air Force 2000 programs are the long-range plans designed to project military needs in the next few decades. Yet there appears to be little coordination between the two Services at the most critical phase, the planning process.

o Army -- The Army planning process is identified in the U.S. Army Chief of Staff Regulation (CSR) No. 11-15, "Army Programs, Army Long-Range Planning System," issued in May 1981. This directs a look "ten to 20 years in the future." The Army recognizes that its planning is structured along program lines (e.g., tactical programs) and has a draft CSR in process titled, "Army Long-Range Research Development and Acquisition Planning." This will become a functional part of the Army long-range planning system described in CSR 11-15. The science and technology plan developed by this process is being issued for the first time in final form (the draft was issued two years ago), as is the first draft of the development and acquisition plan.

Our assessment is that the Army's long-range planning process, as it is being developed for R&D, features all of the basic elements for effective strategic planning. It has the potential of becoming a system for all agencies, not just the Army. The Army agrees that it may take several years to implement and will require the continued attention of Army management from the Chief of Staff through all commands. Like the Air Force, the Army has little or no joint planning efforts with other Services or with OSD.

o Navy -- After extensive discussions with a cross-section of naval R&D management, the issue team found little evidence of a formal, comprehensive long-range planning process for the Navy. It did, however, uncover the initiation of a planning process in Office of Naval Research (ONR). The team reviewed several internal documents issued by the Chief of Naval Research in January 1982, pertinent points of which are summarized below:

- The policy guidance states that "the Naval R&D programs must display characteristics of technical excellence, direction, and emphasis which reflect a clear commitment to the Department needs and priorities."
- "The claimants (program originators) are expected to tailor their projects so as to complement (as opposed to compete with) the programs of DARPA, the other Services, national laboratories, industry and the universities."
- "Claimants are to consider the key naval needs in the formulation of their project proposals and will be required to include an assessment of the relationship of these needs to their proposal."

The issue team saw little evidence from the Navy that a strategic long-range plan was in development. The Service appears to be bogged down with bureaucratic policies and directives; it is not developing a set of goals from which an efficient, mission-directed research program can be derived.

National Aeronautics and Space Administration -- Strategic planning in NASA was developed in the 1960s to support the national goal stated by President Kennedy to put a man on the moon within the decade. That goal statement met the criteria previously identified. Since then, although there have been various statements of NASA's goals, they do not meet the criteria. Because of these inadequacies, recent efforts in strategic planning and the ranking of alternatives toward these goals result in frequent changes in program direction, often derived from political pressure and causing additional wasted expenditures. For example, several politically motivated Congressional directives regarding the type of booster to be utilized in the Galileo program have resulted in more than $100 million of additional expenditures.

Planning, coordination and control of NASA programs are performed at NASA headquarters; the technology centers are responsible for execution. NASA generates a long-range plan that lists details of desired programs. It is apparent from these lists that the majority of project planning and ranking is from the bottom-up rather than top-down, with each center administrator justifying his/her existence and facility.

Department of Energy -- Like NASA, DOE suffers from indirection. Long-range plans are assembled within the Department, but the ranking of alternatives is meaningless without clearly defined goals. As a result, the DOE long-range plan consists primarily of bottom-up project plans. Without adequate goals, DOE is subject to a high degree of micro-management from Congress and lobbying groups.

The issue team saw evidence that DOE managers scrutinize R&D programs and may even drop them if they do not fit their de facto goals. The team also observed that some expensive programs are "forced" on DOE by Congress (for example, the funding of insulation to be added to homes of the poor, which is clearly not a DOE mission). DOE was the only agency evaluated where agency officials stated that their own R&D budget should be reduced (and it was) rather than expanded.

The National Institutes of Health -- In the health arena, the Government primarily supports basic research. Most of this support is through NIH. In health, the Government is not the primary end-user (unlike defense or space) and, for the most part, leaves the application of basic research to the private sector. Thus, the task of strategic planning in health research is more difficult. The NHLBI provides a good example of this process at work.

NHLBI goals are articulated in the 1972 law that established the Institute. Specifically, NHLBI is " . . . to advance the national attack against diseases of the heart and blood vessels, the lungs and blood . . . ." In the absence of more specific goals, NHLBI develops its own. The NHLBI strategic planning process involves an annual update cycle characterized by a continuous flow of information from the public, the biomedical research community, the medical community, other Federal agencies and organizations outside of Government.

As part of this planning process, a series of reports and formal plans are published each year. These documents are prepared by NHLBI staff members to structure and coordinate input from the NHLBI Advisory Council and from committees and consultants. The documents serve as resource materials, implementation plans for program activities, and state-of-the-art assessments. They define program component interrelationships, inform Congress and the Administration of needs for accomplishing the five-year plan, and inform the scientific community about the Institute's accomplishments.

Department of Agriculture -- USDA is in the early stages of developing a strategic plan. The program strategy describes the kind of research that Agricultural Research Service (ARS) scientists identified as necessary to meet the short- and long-term needs of the agricultural sector. In addition, a six-year implementation strategy is being developed to provide guidelines for executing those portions of the plan that ARS believes have a high probability of attaining the stated research objectives. The guidelines seek to assure the most efficient use of available resources in pursuit of the objectives.

These plans are designed to achieve the following ARS goal:

> Through fundamental and applied research, ARS seeks to provide the means to solve the technical food and agricultural problems of broad scope and high national priority as required to assure perpetually an adequate supply of high quality food and fiber for the American people and for export.

The issue team concludes that the elements of this plan closely correspond to elements found in the private sector and will address many of the problems of ranking fundamental research programs. In the absence of more defined Federal goals, the plan outlines key research efforts based upon estimating future demands for food and other agricultural products. The issue team views this plan as potentially one of the best bottom-up processes reviewed within Federal agencies.

3. Evidence of the Inadequacies of Strategic Planning

In the private sector, the strategic plan is the driving force in establishing policy and setting priorities. Because of the lack of adequate goals and the inadequacies of the plans themselves, policy and funding priorities are deferred to the annual budget cycle in the Government.

Ultimately the final program selection is negotiated with the Office of Management and Budget (OMB), whose major interest is control of total budget dollars (rather than balancing national priorities). The annual budget cycle becomes a trade-off between competing laboratories and agencies. Rather than a debate between defined national priorities, the process is a series of negotiations determining how much increase (or decrease) in funding each agency must plan for the fiscal year. Sometimes agencies receive funds they did not request, causing a last-minute rejuggling of their own priorities. Other times, some deserving programs are dropped in favor of a Congressionally supported program stemming from lobbying pressures. A set of defined long-range goals (five to 15 years) for each agency would provide agency management with a stronger mandate to minimize this type of redirection and simplify the planning process for individual agencies, as well as for Congress and OMB.

It is extremely important in R&D planning to achieve a balance between top-down planning and a bottom-up approach. In any Government agency, an absence of the top-down approach permits the bottom-up approach to predominate. This results in unnecessary program duplication between laboratories and agencies and tends to continue programs of marginal value because champions have successfully "sold" them. Some fundamental research projects that are not mission oriented should, of course, be budgeted to encourage creativity and potential spinoff. The majority of R&D programs, however, should be oriented toward defined agency goals, not pet projects. Again, the problem is the absence of formal, top-down guidance regarding the agency's goals that can be translated into requirements, both near and long term.

Present planning techniques often do not include implementation plans and scheduled decision points (milestones), making it difficult to determine progress and make course corrections from prior plans. Without defined strategic planning elements, these key milestones do not exist. Long-range planning should highlight program milestones and provide the needed visibility to minimize the "budget ax" or program redirections that often occur during budget cycles. R&D programs are rarely completed in one year. The annual reviews would be more meaningful if progress could be measured against a projected set of milestones and expenditures.

DOD has no central planning focus. The isolated planning techniques in the Services tend to muddy the planning focus at OSD; OSD exhibits little control of joint programs and does not provide encouragement for cross-fertilization of R&D and weapon systems. USDRE does not exercise leadership in DOD's goal-setting and planning process; there are very few joint Service R&D programs and little cross-fertilization. In fact, the issue team found that USDRE is encouraging greater decentralization. The Air Force, for example, has moved the direction of its many laboratories from a single management point to individual user commands. The issue team members believe that such a step only serves to narrow the planning focus and make cross-fertilization even more difficult and duplication of effort more prevalent.

The degree of isolation is evident by the following:

- Some military Service R&D managers do not even know who their counterparts are in the other military Services.
- Programs within DARPA are not disseminated routinely to the Services.
- Cross-fertilization is rare.

The majority of the longer-range planning done within Federal agencies is not constraint driven. For the most part, agencies employ a bottom-up planning approach and a broad set of agency goals, resulting in a process that forces agency planners to cover all potential contingencies. There is little ranking of issues at each level of the organization to assure that the real issues emerge and are analyzed in light of budget targets. This approach also forces the organization into a "selling mode" early in the process, a hazardous condition and one hard to change as the process rises to senior management.

The planning process fundamentally operates annually; almost all decisions are reviewed and re-reviewed and, indeed, many change from year to year. External pressure from Congress, frequent changes in policy and leaders, and failure of the system to provide a longer term strategic focus cause this kind of short-sightedness. Year-to-year planning is wasteful, particularly for R&D activities that tend to be long term. An enormous amount of time and dollars is eaten up in rejustifying each year's decisions. Agencies can avoid the important issues, since one year's unapproved program can be resubmitted the following year.

4. Implementation of Effective Strategic Planning Should Be Expected To Be Lengthy

Implementation of effective strategic planning in the Government R&D agencies is going to take time. Industry experience seems to indicate that agencies will need a three- to five-year learning process to evolve, refine, communicate, gain acceptance for and achieve a reasonably satisfactory degree of efficiency with respect to strategic planning. Top management must persistently emphasize and support the process if there is to be any hope of success. Even then, according to industry experience, the process of setting goals and strategic planning is a never-ending discipline that must be maintained and continuously improved in order to produce results.

It is not surprising, then, that Government agencies attempting to incorporate long-range strategic planning are experiencing the same frustrations of the learning process. The U.S. Army started to develop its process four to five years ago. The first long-range plan for science and technology only just recently entered the system in draft form. This year's revision to the Army's Science and Technology plan is in final form now and a long-range strategic plan for Development and Acquisition is in draft form. The progress is real, and the Army should be commended and encouraged. Similarly, the Air Force Vanguard program is now being implemented and should produce measurable results by the next fiscal year.

Conclusions

Strategic planning as applied to Government R&D efforts is generally ineffectual in large part because the goals that have been established are not adequate to guide the planning process. Also the process does not work within realistic budget constraints and does not result in implementation plans that clearly spell out actions necessary to meet the goals.

These shortcomings cause the following deficiencies in R&D planning:

- Federal R&D plans do not direct available resources to areas with achievable results.
- Many more R&D programs are initiated than can be funded at either the development or acquisition stage.
- R&D programs are not ranked, which leads to inefficient use of development funds.
- Agency managers often are not able to terminate programs that do not meet cost and performance targets or that are no longer required to meet the mission and goals of the agency.

- There is much program duplication because of lack of cross-fertilization between laboratories, the Services, agencies and users.
- In the absence of formal, top-down guidance on the nation's priorities, Federal R&D programs cannot be effectively translated to meet both the near- and far-term technological requirements.

These deficiencies are identified in several other PPSS Task Force reports. Several of the reports dealing with defense issues pointed to the problem of initiating more R&D programs than can be funded and to problems of priorities. The PPSS Task Force Report on DOE highlights the duplications and problems in the R&D programs because of a lack of clearly articulated goals. In the Report on the Department of Transportation, the Task Force questions the lack of specific focus for that agency's R&D program.

Recommendations

R&D 1-1: Redirect all agency planning efforts to concentrate on developing statements of goals that reflect national and agency priorities. The lack of precision and clarity that exists in current statements of agency and program goals has been documented by the Task Force. Improvements in strategic planning require a major effort on the part of all participants in redefining the goals so that strategic planning can play the essential role that it should.

Goal setting is a discipline, not a sporadic chore. The process, as well as the goals themselves, require constant examination and emphasis. Top management cannot develop goals separately from the line managers and staff responsible for strategy and implementation. Similarly, line managers cannot focus adequate resources to achieve long-range goals they set by themselves. They need top management's concurrence and authority; a top-down, bottom-up mix of management participation is required. A continuous intensive process of this kind is typical of what is sought in the private sector.

In order to develop goals for the Government R&D programs, all levels of the organization must be involved, including OMB, the Office of Science and Technology Policy (OSTP) and the White House staff. The Findings section pointed to the goals for the Strategic Defense Program as the kind of goal statements necessary to guide and direct strategic planning. In order to improve R&D planning the same type of effort will be required in all areas.

The Task Force fully recognizes that the establishment of goals of the type described here is an evolutionary process that cannot be accomplished in a given time frame. In fact it will be a continuing process. Furthermore, it will not be possible to develop adequate goals for all aspects of Government R&D in a year or two. However, we recommend that the agencies initiate the process and develop the discipline necessary to influence strategic planning. Thought and interaction among all levels of the line and staff organization are the essential ingredients.

In order to institutionalize the goal-setting process, we recommend that each agency designate a senior official (at the Assistant Secretary level) to lead the internal effort and to coordinate with other agencies and the Executive Office of the President (EOP) through the Office of Science and Technology Policy (OSTP). Each agency should work with the appropriate Cabinet Council or the National Security Council in establishing the goals for the agency and reviewing the results of the strategic planning process. We recommend that OSTP coordinate the process and provide the necessary assistance in evaluating the adequacy of the goals. In the past, efforts to institutionalize strategic planning have focused on OMB and the associated budget process. This has not been very successful. The success of strategic planning is ultimately related to the commitment of top management. As this management changes, the new managers must assume the leadership role.

R&D 1-2: Develop improved strategic planning concepts and procedures. The Task Force has commented on many of the existing strategic planning systems and procedures. Each agency will require revisions to certain aspects of its systems.

Given the diversity of R&D missions and programs of the agencies we do not feel that a single system can be applied uniformly to all agencies. However, the system developed in each agency should provide for the essential element of strategic planning.

We recommend that each agency adopt a strategic planning process that will meet its needs. The senior official designated to lead the goal-setting effort should coordinate the development of the strategic planning process in the agency. Coordination with other agencies that appear to have effective systems (e.g., the Army and ARS) would be beneficial. However, the organizational and management style of each agency will influence the systems and procedures used.

R&D 1-3: Use strategic planning as the basis for subsequent budgeting and operational management. As the strategic planning process develops and encompasses certain agency activities, those portions of an agency's operations should be driven by it.

Too many strategic planning efforts have failed because they are subjected to rigid timetables. In such cases, the quality of the strategic-planning is inadequate to support the budgeting and operational management. Artificial deadlines lead to inadequate analysis and procedural solutions.

We recommend that the agencies initiate the process immediately and begin the cut-over to budgeting and operational management as the quality of strategic planning permits. For example, we would not be surprised if it took more than five years of concentrated effort to develop an adequate strategic planning process in DOD. Any attempts to tie budgeting and operational management to the strategic plans before then would be counterproductive.

We recommend that each agency set its own pace in implementing strategic planning and that the pace be controlled by the top management of the agency. To ensure that progress is made, the agency should make a commitment to EOP regarding an implementation schedule.

Savings and Impact Analysis

It is difficult to quantify the dollar impact of effective long-range strategic planning. The primary thrust of our recommendations is improved management of the R&D process. Improved management focuses on the effectiveness of the process, not just the cost of conducting the program. The actual savings to be realized are open to debate. Although opinions vary, almost everyone agrees that real savings will result from incorporating long-range strategic planning into R&D operations. From industry's perspective, the process is essential.

One measure of the potential savings in the area can be seen from the PPSS Task Force on OSD. Issue OSD 21 recommended that DOD limit the number of new weapons systems starts based on anticipated funding availability (An effective strategic planning process would achieve this objective.). That Task Force estimated annual savings of $1.1 billion in Research, Development, Test and Evaluation (RDT&E) funds when the recommendations were fully implemented. If these figures were extrapolated to the total R&D budget of the Federal Government (on the basis of total R&D of $44.3

billion versus DOD's R&D of $24.8 billion), the annual savings when fully implemented would be $1.96 billion.

Elimination of R&D starts based on funding availability would be only one aspect of the savings which could be attributed to the implementation of our recommendations in this area. The improved effectiveness of R&D, the ability to more easily eliminate redundant research, and the ability to eliminate programs that do not meet cost and performance standards would add to anticipated savings.

Another approach to estimating potential savings was based on using three sources to develop an estimate of the degree of improvement and potential cost savings that could be expected with the implementation of an effective strategic planning system. These were:

- agency management personnel,
- public interest leaders, and
- senior private sector R&D managers, particularly the Co-chairmen of this Task Force.

It is the Task Force's collective judgment that 10 percent enhanced efficiency is a reasonable estimate. The leaders of several public interest organizations suggested numbers in the 10 to 20 percent range and the estimate of agency management personnel who would cite a figure was in the 10 to 15 percent range.

Accordingly, the Task Force conservatively estimates that the implementation of a strategic planning process would reduce overall R&D costs by 10 percent. However, in view of the complexity of this issue and of the many uncertainties involved, the Task Force recommends half of the claimed savings (5 percent) be viewed as an objective and the other half be claimed as potential savings. Based on the FY 1983 R&D budget of $44.3 billion, first-year savings of $2.2 billion could be anticipated. Using a 10 percent inflation factor, the savings in the second and third years would be $2.4 billion and $2.7 billion, respectively. Total three-year savings potential is $7.3 billion. Given the savings documented by the DOD Task Force, this level of savings appears reasonable.

Implementation

Strategic planning can be implemented by each agency head by means of administrative action. Because of the importance of strategic planning to the operation of each agency, the Task Force believes that specific direction for implementation must come personally from the head of each agency.

II. ISSUE AND RECOMMENDATION SUMMARIES (CONT'D)

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 2: R&D MANAGEMENT AND THE BUDGET PROCESS

Issue and Savings:

Can the detailed process associated with the budget be improved to make the research and development (R&D) management process more efficient?

The Task Force believes that implementation of its recommendations will significantly improve the overall management of R&D. Major savings opportunities are available in the actual R&D and associated procurement funds. Several PPSS Task Forces recommended changes in this area with estimated savings opportunities of $25.9 billion over three years. These savings opportunities impact both the Research, Development, Test and Evaluation (RDT&E) budget and the associated procurement budget. This Task Force estimates three-year savings opportunities of $3.67 billion in the RDT&E budget if major reforms are implemented in the budget process.

Background

All of the Task Forces that dealt with the Department of Defense (DOD) -- the Office of the Secretary of Defense (OSD), Air Force (USAF), Army, and Navy -- as well as the Task Forces on the Departments of Energy (DOE) and Transportation (DOT), and Procurement focused on problems of R&D and weapons systems acquisition caused in part by the annual budget process and the associated single-year procurement policies. These issues all dealt with the instability that results and the opportunities for savings that exist if the instability is removed.

This issue will address several aspects of R&D management directly impacted by the budget process. By definition, this Task Force is only dealing with the R&D phase. Yet, in several agencies, notably DOD and DOE, the R&D process is tied directly to the procurement process and opportunities for savings extend to those phases as well.

The budget process is the mechanism by which the results of planning for R&D and weapons systems are implemented. This process in the U.S. Government is complicated and takes two calendar years or more to complete in any agency for a particular fiscal year. Exhibit II-3 on the following page presents a simplified overview of the budget process for the FY 1983 budget. Individual sub-agency level organizations began their budget preparation activities in the fall of 1980 (particularly for the larger agencies) for the FY 1983 budget. Agency-level reviews and budget preparation activities commenced in the spring of 1981 culminating in the formal submission of the budget to the Office of Management and Budget (OMB) in September 1981.

The OMB budget review and preparation process began immediately upon receipt and extended to January 1982, with the submission of the President's Budget to Congress. During that period, agency personnel were continually on call to defend their budget, appeal decisions made by OMB, and make the necessary revisions to the overall budget package.

Once the President's Budget is submitted to Congress, the focus shifts to the House and Senate appropriation and authorization hearings process. During this phase the agencies must be prepared to testify and respond to the many Congressional committees and subcommittees with jurisdiction over their budget.

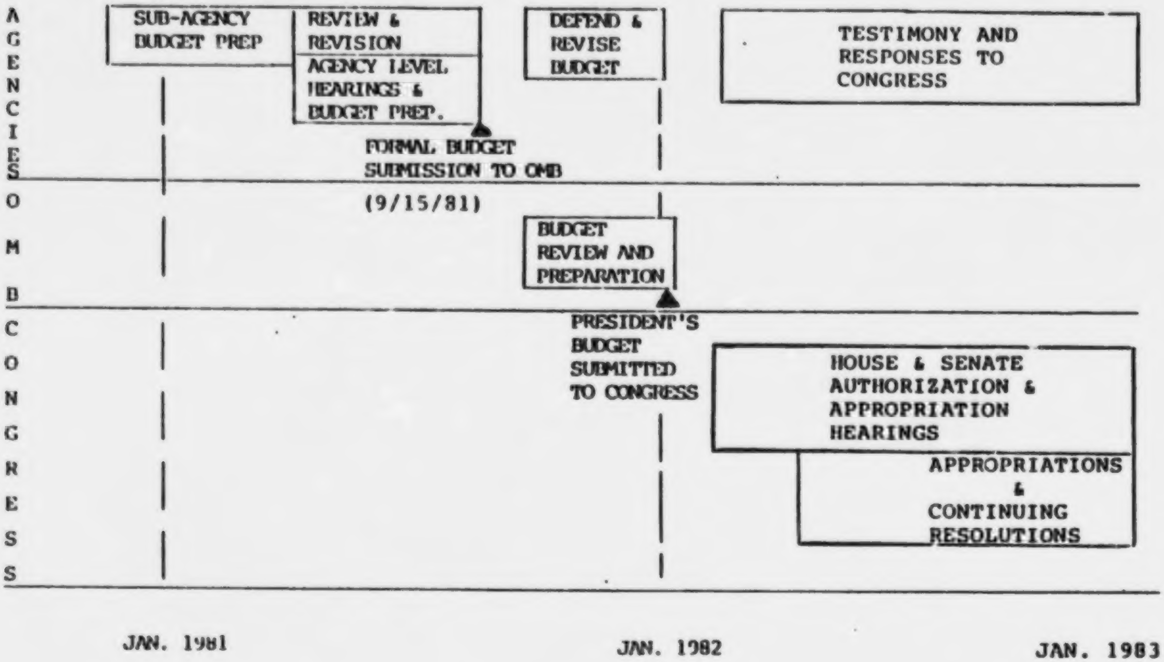
The end result is a series of appropriation bills and resolutions which give the agencies the authority to spend money. For the FY 1983 budget, the completion of the process for the individual appropriations was as follows:

Agency	Date Signed into Law
HUD - Independent Agencies	Sept. 30, 1982
Military Construction	Oct. 15, 1982
Agriculture	Dec. 18, 1982
Transportation	Dec. 18, 1982
District of Columbia	Dec. 23, 1982
Interior	Dec. 30, 1982
(All others were included in the 2nd Joint Resolution)	Dec. 21, 1982

[Exhibit II-3 on following page]

Exhibit II-3

FY 1983 BUDGET PROCESS


AGENCIES
OMB
CONGRESS
SUB-AGENCY BUDGET PREP
REVIEW & REVISION
AGENCY LEVEL HEARINGS & BUDGET PREP.
FORMAL BUDGET SUBMISSION TO OMB (9/15/81)
DEFEND & REVISE BUDGET
TESTIMONY AND RESPONSES TO CONGRESS
BUDGET REVIEW AND PREPARATION
PRESIDENT'S BUDGET SUBMITTED TO CONGRESS
HOUSE & SENATE AUTHORIZATION & APPROPRIATION HEARINGS
APPROPRIATIONS & CONTINUING RESOLUTIONS
JAN. 1981
JAN. 1982
JAN. 1983

That all appropriation activity for the FY 1983 budget was completed by December 1982 reflects the fact that the final session of the 97th Congress was responsible for the bills and any bill not passed by December 31, 1982 would die. In odd-numbered calendar years, when the first session of a Congress is involved, some of the appropriation bills generally are not signed into law until well after the first of the next calendar year, since the same Congress is in session.

Because the agencies cannot legally spend money in any fiscal year until an appropriation is passed, continuing resolutions are used to give them the authority to spend money after October 1. In the case of the FY 1983 budget, the 2nd Joint Resolution included the appropriation language for the other appropriations and had the effect of the normal appropriation bills.

R&D budgets are included in the overall agency budgets and the process for the review and approval of these budgets is the same. There can be one major difference for R&D budgets, however, and that deals with "new starts." Continuing resolutions generally provide that the agency can continue the activities of the prior fiscal year at the prior year's level or the proposed level, whichever is lower. Therefore, when an agency begins operating a fiscal year on a continuing resolution, any new R&D start must wait for the passage of the regular appropriation bill. In certain cases, some new starts are included in the continuing resolutions. This can become a real problem for those budget years handled by the first session of a Congress when certain appropriation bills are not passed until the summer of the fiscal year in question.

Methodology

This issue focuses primarily on the R&D management process in four agencies: DOD, the National Aeronautics and Space Administration (NASA), DOE and the National Institutes of Health (NIH). Interviews were conducted at these agencies with the top management personnel most deeply involved in R&D. In addition, interviews were conducted with staff at OMB, the General Accounting Office (GAO), Office of Science and Technology Policy (OSTP), the Congressional Research Service, Congressional Quarterly, the Committee for a Responsible Budget, and private sector firms with extensive R&D programs. The Task Force also reviewed historical trend data on Congressional and agency operations, comparisons of public and private sector R&D organizations, Congressional committee reports and hearing transcripts, GAO reports, special reports on Federal laboratories and R&D management practice, and various PPSS Task Force reports with issues related to R&D programs.

Findings

In most agencies, budget detail and justification is extensive, requiring information on numerous projects including those of relatively small size. In FY 1983 there are some 1,822 projects in NASA, DOD and DOE for which budget detail is provided. Exhibit II-4, on the following page, provides a summary of the budget justification submitted by the four principal R&D agencies: DOD, NASA, DOE, and HHS (NIH).[1/]

The top half of the exhibit shows that DOD, NASA and DOE supply detailed, project-level information on projects as small as $100,000. The average project size is $9.8 million in NASA and in excess of $31 million in DOD and DOE. In the lower portion of the exhibit, the sized distribution of R&D projects within DOD is shown. Although the average-sized project in DOD is $31.6 million, the distribution data indicate that roughly 75 percent of the projects are smaller than average.

The exhibit also shows a striking contrast between the NASA, DOD and DOE budgets and the NIH budget. In NIH's case, the budget is communicated in terms of total program levels, number of personnel, and an analysis of major program changes for each institute.

The time involved in the budget process is excessive and contributes to the cost growth problem. The two to three years lag in the budget process between initial budget planning and subsequent funding actions makes management and planning difficult tasks. In an R&D environment with its rapid technological change, uncertainty and inflation, planning and management are much more difficult. Time lags of this nature, however, do not cause problems in budgeting such operational functions as medical payments, civil service payroll, and grants and loans.

[Exhibit II-4 on the following page]

1/ The R&D budget justification package for DOD is approximately 3,000 pages; the same package for NASA is 1,000 pages.

Exhibit II-4

FY 1983 R&D FEDERAL BUDGET DETAIL

	No. R&D Projects	Average $/Project ($ millions)	Lowest Level of Project $ ($ millions)
NASA	673	$ 9.8	$0.1
DOD	768*	31.6	0.1
NIH**	NA	NA	NA
DOE	381	31.9	0.1

Analysis of FY 1983 DOD Budget Detail

No. R&D Projects	$1M & Under	$1M-$2M	$2M-$5M	$ 5M-$10M	$10M-$20M	$20M-$30M
Army	10	15	36	42	32	17
Navy	9	25	63	69	55	25
Air Force	9	9	31	31	28	24
Defense Agency	1	5	10	8	15	1
Total	29	54	140	150	130	67
Cumulative total by Service		83	223	373	503	570
% of total (768)	3.8%	10.8%	29.0%	48.6%	65.5%	74.2%

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* Unclassified only.

** NIH R&D budget data are developed in detail within the agency (more than 2,000 in-house R&D projects and more than 15,000 extramural grants). However, summary data are used for communicating and reviewing the budget with emphasis on the total program level, number of personnel, and analysis of year-to-end program changes for each institute.

Because of the lags, R&D budgets are established on the basis of highly uncertain information. In the fall of 1980, program/project managers began developing their detailed budget submissions for expenditures in FY 1983. In an R&D environment where by definition the future is uncertain, developing detailed funding plans that far in the future presents major problems. The problem is exacerbated for new starts where the R&D project is not defined. In these cases the rush to get the project included in the budget to be considered precludes the kind of definitional planning that should be done. A NASA study of the cost growth problem (the Hearst Study) cited inadequate definition prior to the budget decisions as an element contributing to the cost growth.

The lack of definition and the lead times involved can cause subsequent cost growth in R&D projects because the initially requested amounts become commitments on the part of program managers. By the time the budgeted amounts are available for spending, technology changes and the results of the prior years R&D efforts may indicate that a different amount of money is required. In such cases, program managers first try to live within the assigned ceilings by revising the scope of the project or changing the schedule. When they do, they are caught in the situation that leads to real cost growth. Many recent reports on cost growth [the Rand Corporation's "Acquisition Policy Effectiveness" and the Air Force Systems Command (AFSC) "Affordable Acquisition Approach"] have shown that program stretch-outs and changes in technical requirements are contributing factors to cost growth.

In the AFSC study of cost growth, they found funding instability as the cost and schedule growth factor that occurred most often. External management impacts (defined as the occurrence of program decisions above the program office or the occurrence of frequent program reviews at USAF headquarters or higher) was the fourth most prevalent factor in cost and schedule growth.

The budget cycle in the private sector does not involve any delays of the magnitude encountered in the Government. Relying on our own experience and based on information obtained from other private sector firms, we have developed the following general scenario explaining how R&D programs are budgeted in the private sector.

- New projects are generally included in the overall five- to ten-year strategic plan which receives general approval. The projects are described in brief terms and budgets are stated in ranges of dollars such as $50-$75 million.

- When it comes time to approve a specific project, detailed plans and a budget are prepared. They are then submitted to the Board for approval. This whole review and approval cycle generally takes 30-60 days. In general, this approval process is outside the annual budget cycle.
- If annual approval is required for continuation of the project, it is generally handled as part of the normal budget cycle which takes two to four months.

We do not mean to imply that the Federal R&D budget process should adopt the same specific type of schedule as in the private sector. We recognize that in the private sector decisions are made on project proposals by an individual or a small group. In the Government, decisions require a consensus in the agency, the Executive Office of the President, and Congress. Nevertheless, the length of the process is a major management problem and it should be shortened.

The Congressional hearings process places a significant burden on the agency. There are 30 Congressional committees and subcommittees that have jurisdiction over DOE. In the 97th Congress alone, DOE presented over 700 witnesses at more than 300 hearings. This problem is not unique to DOE. Other agencies have found themselves appearing before an expanding array of Congressional committees. In the case of DOD, for example, they have recently had to appear before the Interior and House Ways and Means Committees, in addition to their numerous appearances before the Armed Services and Appropriations Committees. Each of these hearings requires time for preparation of testimony. In addition, considerable time is required to respond to written requests for information on the part of the Committee, most of which are generated by growing staffs.

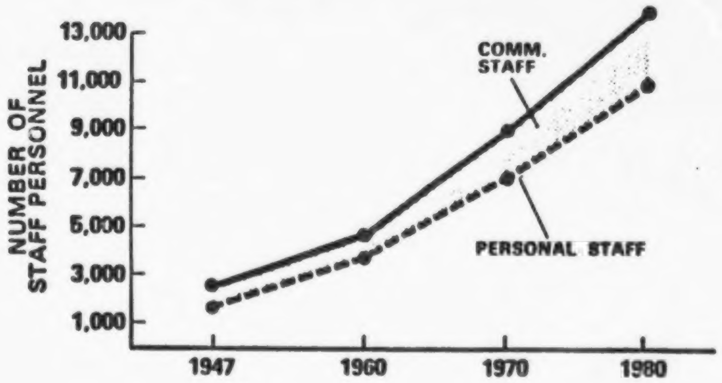
Since World World II, Congressional staffs have increased about sixfold (See Exhibit II-5 on the following page). The Committee staffs, as opposed to the personal staffs of individual members of Congress, have grown 11.7 times in 33 years (1947-1980). Exhibit II-6 shows the growth in staff for those key committees which most influence the four large R&D agencies. The House Energy and Commerce and Public Works Committee staffs alone have increased by a factor of 16, and the number of staff members on a single committee, Energy and Commerce, has reached 165. Despite this growth, the actual number of committees has grown only 25 percent since 1955-56.

[Exhibits II-5 and II-6 on the following pages]

EXHIBIT II-5

CONGRESSIONAL STAFF SIZE 1947-1980

(PERSONAL AND COMMITTEE STAFF)



					1980-1947 RATIO
PERSONAL STAFF1/	2,030	3,556*	7,706**	11,117	5.5 TO 1.0
COMMITTEE STAFF2/	293	641	1,079	3,449***	11.7 TO 1.0
COMBINED TOTAL	2,323	4,197	8,785	14,566	6.3 TO 1.0

*1957
**1972
***1981

SOURCE: (1) VITAL STATISTICS ON CONGRESS, 1980
(2) OFFICIAL PAYROLL RECORDS OF HOUSE AND SENATE

Exhibit II-6

CONGRESSIONAL STAFF SIZE (R&D OVERSIGHT COMMITTEES)

Number of Committees in the House and Senate (1955-1980)

	84th Cong. (1955-56)	90th Cong. (1967-68)	92nd Cong. (1971-72)	97th Cong. (1981-82)
Total Number of Congressional Committees	242	315	333	310

Congressional Staff Size -- Key R&D Oversight Committees

House Committees	1947	1960	1970	1981	1981 to 1947 Ratio
o Appropriations	32	51	71	140	4.4 to 1.0
o Energy & Commerce	10	41	47	165	16.5 to 1.0
o Science & Technology	--	16	29	88	5.5 to 1.0
o Public Works	6	24	43	95	15.8 to 1.0
o Armed Services	10	16	40	54	5.4 to 1.0
o Education & Labor	10	20	102	135	13.5 to 1.0
Senate Committees					
o Appropriations	21	25	33	84	4.0 to 1.0
o Commerce, Science and Transportation	7	10	10	115	16.4 to 1.0
o Energy and Natural Resources	10	10	10	56	5.6 to 1.0
o Armed Services	9	9	8	42	4.6 to 1.0
o Labor and Human Resources	7	22	34	134	19.1 to 1.0

Source: Official Payroll Records of House and Senate.

The argument often used to justify this growth is the increased complexity in running the Federal Government. However, even by Government standards this growth appears excessive. For example, Exhibit II-7, on the following page, shows that civilian and military Federal employment in the Executive Branch has increased less than 50 percent over the same period (about the same growth as the United States population) including the growth in military personnel resulting from the Vietnam conflict.

Both the internal agency review process and the OMB and Congressional review process have created extensive layering in Federal R&D agencies. This results in excessive use of technical staff and micromanagement at numerous and high levels within the agencies. Large technical staffs are used to evaluate programs and advise upper management. These technical staffs who support the management structure do not have direct line responsibility (i.e., they do not manage or have responsibility for a program or function). The use of these technical staffs has grown to the point where it undermines the authority and responsibility concept of management. The staffs are so large that they have an organization and layered structure of their own.

Two of the Task Forces specifically addressed this issue as it applies to R&D.

- o The Department of the Air Force Task Force recommended changes in the Air Force budget preparation and review cycle. They found that virtually the entire Air Staff is involved in the preparation or defense of the Program Objective Memorandum (POM) and the budget which are done sequentially. The Task Force recommended that the Planning, Programming and Budget System (PPBS) reviews and budget reviews be done at the same time and estimated that 120,000 staff-hours could be saved in the process. This analysis focuses primarily on the resources used in the internal agency review process. It does not address the staff required to respond to the Congressional deliberations phase of the budget process.

- o The Department of Energy Task Force found an unnecessarily expensive structure of program direction and support in the Department and labs. They found a complex network of program managers and control personnel involving successive layers of people who oversee, monitor and

[Exhibit II-7 on the following page]

Exhibit II-7

FEDERAL EMPLOYMENT COMPARED TO CONGRESSIONAL STAFF SIZE

	1947	1960	1970	1980	1980 to 1947 ratio
Full-time civilian employment (Executive Branch)	2,082,000	2,371,000	2,994,000	2,821,000	1.35 to 1.0
Uniformed military employment	1,583,000	2,837,000	3,477,000	2,366,000	1.49 to 1.0
Combined civilian and military Federal employment	3,665,000	5,208,000	6,421,000	5,187,000	1.42 to 1.0
U.S. population	144,698,000	180,584,000	205,052,000	228,297,000	1.58 to 1.0
Congressional staff committee size	293	641	1,079	3,449	11.7 to 1.0

Source: Federal Budget Special Analysis F: FY 1969, and Special Analysis I: FY 1983; Official Payroll Records of House and Senate.

> often participate in the management of laboratory programs. Their recommendations for improving the situation would eliminate 600 positions in DOE and 1,800 positions in the GOCOs (Government-Owned, Contractor-Operated facility).

We analyzed the R&D management structure in the Army and compared it to the private sector. The results of this analysis are shown in Figure II-1 and II-2 which follow this page. Figure II-1 presents the current R&D organization and technical staff in the Army. (All nontechnical staff, of which there are many, are not shown.) As shown in this exhibit, there are roughly 600 people involved in technical staff positions with respect to the Army R&D program.

This use of technical staff in the Government is extensive when compared to private sector R&D organizations. Figure II-2 shows an organizational chart for a typical industrial R&D firm. In this example, no technical staff serve in the top management structure. While Government may not operate like industry, the striking difference between these two examples cannot be justified in the organization. In our interviews with Army R&D management, they continually referred to this problem, pointing out that many people have to be lined up to make relatively simple decisions. Many can veto a decision but very few can give a go-ahead. This causes frustrating delays, lack of accountability and great waste in R&D program management resources.

These staff problems are caused, as shown by the Air Force example, by internal management inefficiencies, by the extensive micromanagement practiced internally as well as by external agencies, and by the Congressional budget process. To illustrate the magnitude of the problem, we analyzed the DOD RDT&E budget for FY 1983 and the control procedures used by Congress.

As noted previously in Exhibit II-4, there are 768 unclassified items in the DOD R&D budget. There is agreement between DOD and Congress that the Secretary of Defense has the authority to reprogram funds up to $5 million without prior Congressional approval. However, this agreement also contains the provision that reprogramming of any individual item changed by Congress in the budget deliberations cannot be done without prior approval of Congress. A review of the FY 1983 RDT&E budget reveals that roughly 90 percent of the items were altered during Congressional deliberations. This has the effect of eliminating the reprogramming authority.

[Figures II-1 and II-2 on the following pages]

Figure II-1

DOD (ARMY) ORGANIZATION CHART

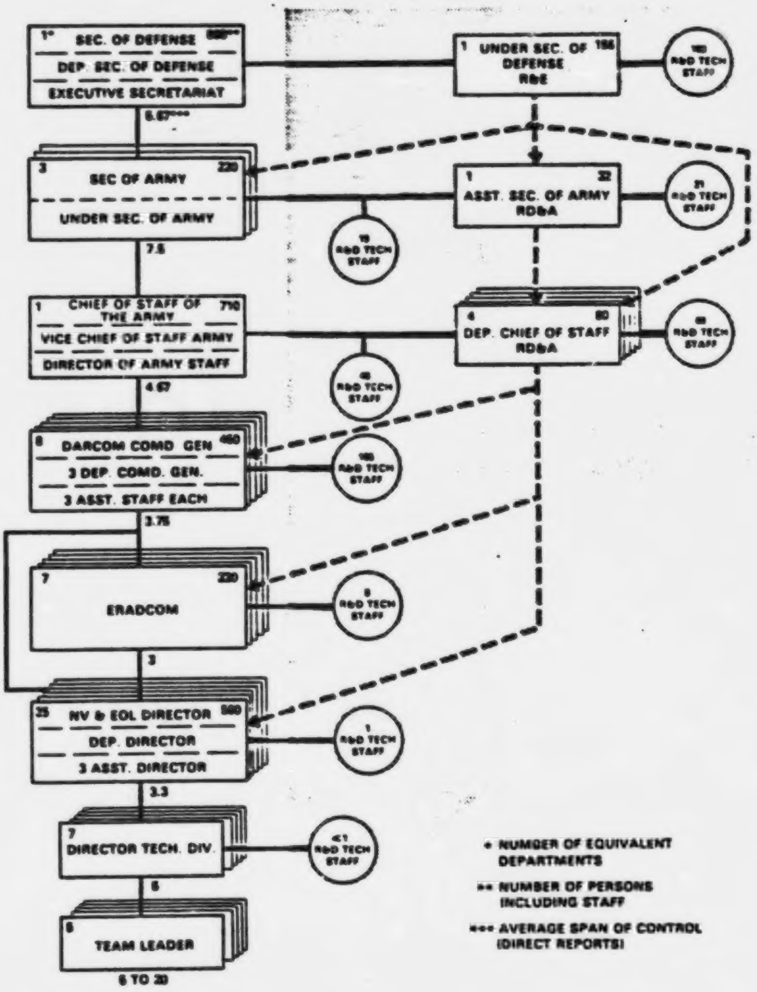
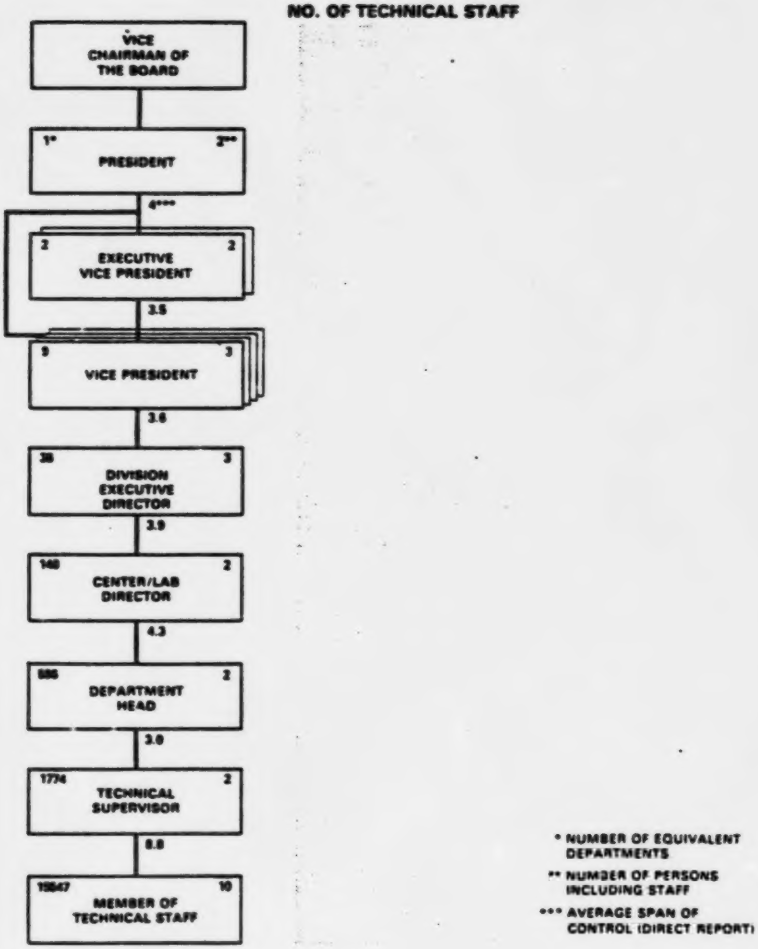

1*
SEC. OF DEFENSE
DEP. SEC. OF DEFENSE
EXECUTIVE SECRETARIAT
5.67***
1
UNDER SEC. OF DEFENSE R&E
156
R&D TECH STAFF
3
SEC OF ARMY
UNDER SEC. OF ARMY
220
7.5
R&D TECH STAFF
1
ASST. SEC. OF ARMY RD&A
32
21
R&D TECH STAFF
1
CHIEF OF STAFF OF THE ARMY
VICE CHIEF OF STAFF ARMY
DIRECTOR OF ARMY STAFF
710
4.67
R&D TECH STAFF
4
DEP. CHIEF OF STAFF RD&A
80
R&D TECH STAFF
8
DARCOM COMD. GEN
3 DEP. COMD. GEN.
3 ASST. STAFF EACH
460
R&D TECH STAFF
3.75
7
ERADCOM
220
R&D TECH STAFF
3
25
NV & EOL DIRECTOR
DEP. DIRECTOR
3 ASST. DIRECTOR
500
1
R&D TECH STAFF
3.3
7
DIRECTOR TECH. DIV.
<1
R&D TECH STAFF
6
6
TEAM LEADER
6 TO 20
* NUMBER OF EQUIVALENT DEPARTMENTS
** NUMBER OF PERSONS INCLUDING STAFF
*** AVERAGE SPAN OF CONTROL (DIRECT REPORTS)

Figure II-2

$2 BILLION INDUSTRIAL R&D FIRM


NO. OF TECHNICAL STAFF
VICE CHAIRMAN OF THE BOARD
1*
PRESIDENT
2**
4***
2
EXECUTIVE VICE PRESIDENT
2
3.5
9
VICE PRESIDENT
3
3.6
38
DIVISION EXECUTIVE DIRECTOR
3
3.9
140
CENTER/LAB DIRECTOR
2
4.3
586
DEPARTMENT HEAD
2
3.0
1774
TECHNICAL SUPERVISOR
2
8.8
15647
MEMBER OF TECHNICAL STAFF
10
* NUMBER OF EQUIVALENT DEPARTMENTS
** NUMBER OF PERSONS INCLUDING STAFF
*** AVERAGE SPAN OF CONTROL (DIRECT REPORT)

The impact of this micromanagement and internal processes in DOD and DOE can be seen in the following table 2/ which compares Government and private sector management ratios.

Organization	No. of Managers & Supervisors	Total No. of Employees	Management Ratio	Average No. of Workers Per Manager
Federal Government Dept				
Defense	138,066	668,150	20.7%	3.8
Energy	2,776	17,298	16.1%	5.2
Private Sector Company				
IBM	45,600	364,796	12.5%	7.0
Exxon	25,604	173,000	14.8%	5.8
Honeywell	12,228	94,062	13.0%	6.7
3M	14,856	87,388	17.0%	4.9
Hewlett-Packard	10,608	68,000	15.6%	5.4

As can be seen in these figures, the average number of workers per manager, particularly in DOD, is low in comparison to major technology oriented private sector firms.

2/ The table is extracted from a PPSS Special Report on Organizational Effectiveness to be released during November 1983.

Conclusions

As shown in the Findings, the R&D management process, particularly those processes dealing with the annual budget cycle, are inefficient, lead to tremendous administrative burdens, and contribute to the cost growth being experienced by many R&D programs. All aspects of this process require change to reduce the time lags involved as well as the level of detail required. The problem of excess staffs in both the Executive and Legislative Branches is, to a certain extent, a chicken and egg argument. From one perspective, they are needed to handle the growing complexity and level of detail involved. From another, the complexity and level of detail are growing because of these staffs.

At the same time, the Task Force recognizes that the process can not be governed by the desired efficiency in R&D management. The system of checks and balances built into the system, as inefficient as they might be, has served the country well. Nevertheless, the Task Force is convinced that certain fundamental changes can be made which will improve the efficiency of the process without harming the other objectives served by the process.

Recommendations

R&D 2-1: Implement multiyear budgeting specifically for R&D activities. The Task Force on Federal Management Systems has recommended that multiyear budgeting be con- sidered as an issue for further study. Many of the other task forces have recommended that multiyear budgeting be implemented for various portions of Government operations including R&D and weapons systems procurement. This Task Force believes that this concept will be helpful in solving some of the problems associated with R&D management, parti- cularly eliminating some of the annual effort involved in budget preparation and review. Such an approach would also provide more stability to the R&D efforts, providing known funding levels for future years of essential R&D programs.

R&D 2-2: Develop a budget concept that significantly reduces the level of detail in the budgeting of R&D programs. As noted in the Findings section, the approval of budgets for 1,822 individual projects for DOD, DOE and NASA gets into an excessive level of detail. At the other extreme, if the R&D budget for the three Services, DOE and NASA were approved at a total level, the Congress would not be exercising the degree of oversight appropriate to its role.

The Task Force recommends that the budget for the DOD R&D program be presented in terms of the three Services and further broken down into the existing budget activities (technology base, advanced technology development, strategic programs, tactical programs, intelligence and communications, and defense-wide mission support). Within each budget activity two or three major programs would be identified for information purposes only.

There are alternative structures that could be used for these budget activities. In the Army, for example, it might be more meaningful to break the R&D budget down into the following functions:

- armament,
- aviation,
- communication,
- mobility equipment,
- missiles,
- tanks, and
- troop support.

A similar functional list could be prepared for the other Services, DOE and NASA.

The Task Force is not in a position to specify the categories that should be used. However, some scheme to get to more summary level information as currently used by NIH should be developed.

R&D 2-3: Develop ways to shorten the budget preparation and review cycle. Certain recommendations contained in this Report should shorten the current budget cycle. The recommendations dealing with strategic planning should significantly reduce the time required for the individual agencies to prepare the budget package for submission to OMB. Also the recommendations for multiyear budgeting would eliminate the annual cycle of the budget process. The largest portion of the cycle that has not been addressed is that taken up by the Congressional deliberations. We recognize that this portion of the cycle is outside the scope of the PPSS review. Yet, we must note that it is contributing to the inefficiencies in Government operations.

Various Congressional budget reforms have been recommended over the course of the last several years. One of the strongest arguments has been made by Dr. Alice Rivlin, former Director of the Congressional Budget Office. She believes that Congress has overloaded its own decision-making process. As one step to simplify the process and reduce this load, she has repeatedly recommended that Congress adopt a multiyear budgeting process. Similar recommendations on budget reform have been advanced by the current and the former GAO Comptroller General, as well as many individual Congressmen.

As part of the negotiation with Congress, which will be required to implement multiyear budgeting and the reduction in the level of detail contained in the budget, the Executive Branch should explore ways to reduce the time required for Congressional review. One alternative might be to separate substantive program review (authorizations) from the formal budget cycle (appropriations), i.e., approve a funding level for the entire R&D program and establish an authorization cycle that is not tied to appropriations. A second alternative might involve the scheduling of R&D deliberations early in the overall cycle in order to shorten the time frame.

R&D 2-4: Reduce technical staff positions in all R&D agencies. The preceding recommendations are directed toward streamlining and revising the R&D management process, particularly the budget process. As these recommendations are implemented there will be an opportunity to reduce the technical staffs that have developed in the R&D management process.

It is recommended that the number of technical staff and support personnel in R&D organizations be reduced to eliminate confusing lines of authority and unproductive staff work. Because the Task Force did not have the resources to analyze the staffing of R&D management agencies, it is not possible to specify the number of positions that should be eliminated.

A PPSS special report on Organizational Effectiveness, which will be released in November 1983, recommends a program for achieving a more effective Government organization structure. Implementation of these recommendations, in conjunction with the changes recommended in the report, should result in an improved R&D management process, operating with a reduced technical staff.

Savings and Impact Analysis

The recommendations presented in this issue should result in reductions in cost growth and savings in acquisition costs through improved program stability. In part, these savings have been addressed in R&D 1 and the various

PPSS reports dealing with the agencies with primary R&D responsibility. On the following page is a listing of the recommendations for multiyear budgeting/procurement and the savings opportunities that have been identified in other PPSS reports. 3/

These savings opportunities apply to both R&D and procurement funds and there is some duplication between the items, so the total cannot be claimed as savings opportunities for this analysis.

In order to attribute savings opportunities to these recommendations the analysis used in ENERGY 13 will serve as the base. In that issue, the Task Force used 5 percent of the R&D budget as the estimated savings opportunities attributable to multiyear budgeting.4/ Recognizing that we are applying the rate to a larger base, this Task Force will use a 2.5 percent rate as the annual savings opportunities attributable to the budget reforms recommended in this issue. Based on the FY 1983 R&D budget of $44.3 billion, first-year savings opportunities would be $1.11 billion. Applying a 10 percent inflation rate, second-year savings would be $1.22 billion and third-year savings would be $1.34 billion. Total three-year savings would be $3.67 billion.

Implementation

Implementation of these recommendations will require Congressional approval. OMB and the affected agencies should initiate discussions with the appropriate Congressional staff to begin working out the revised procedures.

3/ The Task Force recognizes that the recommendations for multiyear procurement do not necessarily imply a need for multiyear budgeting. However, the increased stability provided by multiyear budgeting would greatly enhance the recommendations. Also the implementation of multiyear budgeting does not obviate the need for multiyear procurement authority.

4/ In the OSD report (OSD 23), a 7.5 percent factor was estimated for savings attributable to multiyear budgeting.

Multiyear Budgeting/Procurement Savings Opportunities

Task Force/ Issue	Title	Three-year Savings Opportunities ($ millions)
ARMY 11:	Fully funded biennial budget for major weapon system procurement	$ 6,600.0
ENERGY 13:	Introduce three-year budgeting	413.7
NAVY 1:	Improvements in program stability including a two-year budget	3,000.0
OSD 23:	Reduce instability in the weapons acquisition process	7,185.0
PROC 4:	Expand multiyear contracting to all agencies	3,415.0
PROC 6:	Develop program management and acquisition plan	2,940.0
USAF 19:	Increase use of multiyear procurement and propose a multiyear budget	2,400.0
	Total savings opportunities	$25,953.7

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 3: PRIVATIZATION

Issue and Savings

Can cost savings be realized if the Government privatizes certain Federal research and development (R&D) undertakings?

The Federal Government has a recognized role to play in supporting R&D in the United States, but areas exist where transfer of R&D responsibilities to non-Government entities would generate cost savings and strengthen R&D capabilities.

Background

According to the President's Private Sector Survey (PPSS) Task Force Report on Privatization, "Privatization, in a literal sense, means to turn over an activity, or part of an activity, currently performed by the Federal Government to a non-Federal entity." The Federal Government often becomes initially involved in activities for legitimate reasons. For example, military commissaries arose in the 1860s when the typical army post was a frontier post, miles from the nearest city. The most cost-effective way to provide military personnel with food and supplies was to make the Federal Government their grocer. However, the circumstances that originally justify Government production of goods and services often change, so that eventually non-Federal entities can and should take over production.

In the R&D arena, Government clearly has a role to play in supporting and undertaking R&D activities. Consider the Government role in the following cases:

R&D That Entails Major Expenses, But Whose Outcome Is Highly Risky -- There are scientific and technological areas important to the United States that are too expensive and risky to be developed by the private sector. In such cases, the Federal Government can appropriately become involved in relevant R&D activities. For example, the Federal Government's willingness to underwrite the risks involved in the transistor's early exploitation.

Very Long-term R&D -- Some R&D work involves planning horizons that extend beyond the normal planning horizons of industry. It is appropriate for the Federal Government to support actively such R&D. If significant progress in fusion-based energy system research is to be realized, Government must play an active role in its development..

Public Good Areas -- The Federal Government is clearly responsible for doing such things as maintaining the national defense and assuring the existence of a good public health system.

Maintenance of the National R&D Infrastructure -- Only the Federal Government possesses a national perspective on R&D. For example, while an individual electronics firm may be concerned about where it will find electrical engineers to fill staff openings in its labs, the Federal Government is concerned with having an adequate supply of electrical engineers to meet all the corporate and non-corporate needs of the United States. It is also concerned with developing an adequate cadre of scientists and engineers in all other areas of science and technology.

Maintenance of the U.S. Competitive Position in Crucial Areas -- While we are far from having universal agreement on this matter, there are many who believe that the Federal Government should do whatever is necessary to make certain that the U.S. does not lose its leadership position in certain key scientific and technological areas; e.g., in electronics, computers, and aerospace. This view has arisen in response to foreign challenges to American dominance in these areas, challenges that have their origins in foreign government subsidies of their domestic R&D efforts (e.g., in Japan, France, and many Third World countries).

While Government has an important role to play in supporting R&D efforts, care must be taken to make certain that legitimate Government-supported efforts do not, over time, become incursions into non-Governmental terrain.

Methodology

The R&D-related issues of all the PPSS Task Forces were reviewed to identify areas where Federally supported R&D can be privatized across a broad spectrum of Federal agencies. Interviews were conducted with high level personnel in both the Federal and non-Federal sectors. Relevant literature was reviewed.

Findings

The PPSS Task Force on Privatization made a distinction between the Federal Government providing goods or services and producing them. There are many goods and services that the Federal Government can legitimately provide to the public, but the number that it should produce is far smaller. In this scheme of things, privatization primarily entails reducing the Federal Government's role as a producer of goods and services.

In our Report, we carry the concept of privatization even further. Our investigations have led us to the following three broad findings:

- The Federal Government should divest itself of R&D tasks:
  - that would otherwise be effectively done were the Government is not involved.
  - that can more efficiently be done by non-Government entities.
- The Federal Government should create an environment that stimulates increased non-Federal R&D activity in certain target areas.
- Non*Federal entities should be profitably encouraged to use Federal R&D facilities and the results of Federally sponsored R&D.

There are two basic ways to accomplish divestiture. One way is to farm out to non-Government entities tasks that Government legitimately needs to have performed. Thus, while Government would provide necessary R&D services, it would not be producing them itself. Examples include the environmental testing done by Environmental Protection Agency (EPA) field workers throughout the United

States, and the later development phases of Department of Defenses (DOD) research.

The Federal Government can also divest itself of R&D undertakings by getting out certain R&D areas entirely. This should happen when it is obvious that the R&D would be carried out by non-Federal entities even without Government involvement, or when it is determined that the R&D is not meritorious for Federal involvement. It is assumed that R&D projects that were meritorious from the private sector point view would be picked up. The following are some specific examples of programs that the Federal Government should divest itself of:

- The PPSS Task Force examining the Tennessee Valley Authority (TVA) determined that the Federal Government should phase out its support of the National Fertilizer Development Center (NFDC). The NFDC has been quite successful in carrying out its mission. At this point private funding sources can support NFDC's work. A gradual phase-out of Government support would yield a savings of $12.1 million in the first year, $27.1 million in the second year, and $44.6 million in the third, for a total three-year savings of $83.8 million (See BUS-TVA 7).

- In reviewing the Cooperative State Research Service (CSRS), the PPSS Task Force on the Department of Agriculture found that 20 low priority CSRS projects could be dropped by the Federal Government, transferred out of the Agriculture Department to other agencies or transferred to non-Government entities. Those projects transferred to non-Federal entities would save the Federal Government over $10 million a year in expenses, for a total savings of $35.4 million over three years (See AG 54).

- The PPSS Task Force on the Department of Energy (DOE) concluded that DOE should not support projects that can be adequately handled by the private sector (e.g., ocean thermal energy conversion). While the Task Force did not suggest a dollar figure for the savings realized by privatizing certain energy R&D efforts, it is clear that the savings would be very large, ranging in the hundreds of millions or even billions of dollars (See DOE 11). 1/

- The PPSS Task Force on Privatization determined that if funds for the fifth space shuttle were collected from the private investors, cost avoidances totaling $460 million in the first year, $506 million in the second year, and $556.6 million in the third year could be realized for a three-year total of $1,522.6 million. Currently, two shuttles have been procured and constructed with two more in the works. There are no plans for a fifth shuttle. However, it seems clear that the demand for space shuttle services will exceed the capacity of the four shuttles, so that it is reasonable to assume that a fifth shuttle will have to be built. By bringing private investors into the procurement of the fifth shuttle, the Federal Government would be making a significant step in privatizing what will some day be a major American industry (See PRIVATE 3).

It should be recognized that privatization can be encouraged through indirect means. By creating an environment that reduces the level of risk in R&D investments, the Federal Government can stimulate increased R&D activity in the areas that the private sector normally avoids.

The Federal Government should continue to explore mechanisms such as the R&D tax credit, the R&D limited partnership (R&D LP) and R&D joint ventures (R&D JVs).

The Federal Government undertakes large quantities of R&D either in-house or through contracts. A significant consequence is R&D assets valued in the billions of dollars. These take the form of laboratories, equipment, production facilities, and a large cadre of well-trained scientists and engineers. They also include control over an enormous amount of technology patented by the Federal Government. To the extent that these assets are amassed by the Government, they are not being utilized effectively. The R&D Task Force suggests that attention focus on the

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1/ It has been estimated that the annual savings in Federal outlays for energy research could amount to $2 billion, with greater future savings (Heritage Foundation, Backgrounder $270, "Privatizing Federal Energy Research," June 7, 1983).

following three ways of increasing the flow of technology from the Federal to the non-Federal sector:

- o Non-Federal entities can be given improved access to the facilities of Federal laboratories.
- o Information on Federally supported efforts can be more effectively disseminated to the public.
- o Non-Federal entities can be encouraged to license Government-owned patented technology.

While the second and third items are discussed in separate issues in this Report, improved access to the facilities of Federal laboratories is briefly discussed here. DOE labs have "user facilities" in which either Government or commercial entities can pay to have experiments conducted or analyses made. A prime example is Brookhaven National Laboratory's Synchotron Light Source, a unique diagnostic tool for studying such commercially important materials as alloys, catalysts, and polymers. The facility is available on a time-sharing basis. Despite recent publicity, some potential users (including large beneficiaries) may still not know of the facilities existence, much less its possible application to problems with which they are concerned.

Various gains can be realized from closer interaction between the national laboratories and the private sector. The private sector would get access to specialized equipment and expertise, in addition to gaining insights into high-risk, long-term work being performed at the labs that may ultimately have commercial significance. For its part, the laboratories would get a clearer value. They would also be able to identify and discontinue research in the Government sector that private companies and research institutions are already performing.

Conclusions

The Federal Government has a legitimate role to play in R&D. This is particularly important for maintaining the national science and technology infrastructure and in the areas of long-term, high-risk R&D and public good-related R&D. However, the Government must be wary of undertaking R&D efforts that could be adequately undertaken by non-Government entities.

There are many R&D efforts currently funded by the Federal Government that should be turned over to the private sector, or abandoned if the private sector is not interested. The two most noteworthy examples are the Clinch

River Breeder Reactor Project and the National Fertilizer Development Center.

There are several different ways in which privatization of Federal R&D can occur. The Government can directly transfer Federally related R&D task to non-Government entities; it can divest itself fully of tasks which it should not be performing; it can create an atmosphere that encourages greater private sector participation in high-risk, long-term R&D ventures; and it can encourage non-Government entities to take better advantage of the fruits of Government-sponsored R&D.

Recommendations

R&D 3-1: Federal agencies should identify areas where they provide R&D goods and services that can better be produced by non-Federal entities. Where logical, they should strive to transfer the production of these goods and services to non-Federal entities.

R&D 3-2: Federal agencies should periodically assess the R&D activities they support to identify activities no longer deserving support on the grounds that they compete with the efforts of the private sector or are not worthy of Federal sponsorship. Where logical, the agencies should divest themselves of these activities in their entirety.

R&D 3-3: The Federal Government should strive to create an environment that encourages increased private sector participation in high-risk, long-term projects by expanding R&D tax credits, and R&D incentives like R&D limited partnerships and joint ventures.

Savings and Impact Analysis

The majority of benefits derived from privatizing R&D cannot be readily quantified. For example, it is difficult to speculate on the value of increased tax revenues gained for successful privatization or cost savings that might be realized by letting market forces increase the productivity of the R&D process.

To illustrate the savings potential from privatization of R&D, we have summarized the savings identified by other Task Forces in the table on the following page.

Cost Savings/Avoidance

($ millions)

Source of Savings	Year 1	Year 2	Year 3	Three-year Total
National Fertilizer Development Center	$ 12.1	$ 27.1	$ 44.6	$ 83.8
Cooperative State Research Service	10.7	11.8	12.9	35.4
Clinch River Breeder Reactor 2/	200.0	200.0	200.0	600.0
5th Space Shuttle	460.0	506.0	556.6	1,522.6
Total	$682.8	$744.9	$814.1	$2,241.8

These savings are shown here for illustration purposes only since they have been included in the other Task Force reports. They are not counted as savings attributable to this issue, but are included in the Compendium Issue (R&D 8).

Implementation

Statutory and administrative authority exists to implement all the recommendations offered here (e.g., Stevenson-Wydler Act, OMB Circular A-76). Implementation can be undertaken at the agency level.

2/ The savings for the Clinch River Breeder Reactor are estimated since there are no annual appropriation requests for the project. In FY 1983, $194 billion was appropriated for the project. DOE requested that Congress appropriate $1.5 billion to be obligated through 1990 which, when combined with planned private sector funding would complete the project. Therefore, it was assumed that $600 million would be saved in three year. Total savings through 1990 would be $1.5 billion.

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 4: IMPROVED MANAGEMENT OF RESOURCES IN FEDERAL RESEARCH LABORATORIES

Issue and Savings

Can Federal research and development (R&D) costs be reduced by managing funds, personnel, facilities and equipment of Federal research laboratories more effectively?

Savings from improved resource management are estimated to be $153.0 million in the first year, $168.3 million in the second year, and $185.1 million in the third year for three-year total savings of $506.4 million.

Background

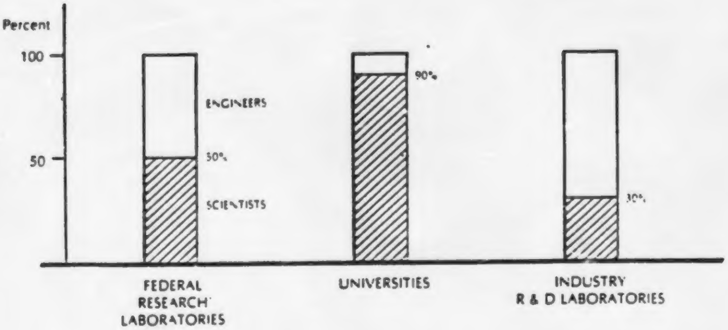
Over the past ten years, there has been an upward trend (in constant dollars) in total Federal funding for R&D, which is conducted in three major performing sectors: industry, Federal laboratories, and universities.. The fraction going to Federal laboratories has been relatively constant over that period. In general, industry is principally involved in development, the Federal laboratories in development and applied research, and universities in basic research (see Exhibit II-8 on the following page). There are, however, many exceptions. The overlapping capabilities among the three performing sectors in many areas of endeavor make it increasingly difficult to identify capabilities truly unique to any one sector. In addition, all sectors need to maintain some level of activity in basic science and engineering to support the more applied aspects of their work.

The Federal laboratories, however, share a common role and purpose. They provide scientific and technical services to the sponsoring agencies that manage them. Through their research, they contribute to agency planning, program development and policymaking. Many of the laboratories' original objectives have been met, however, and some of the missions are no longer relevant. Also, industry and the universities now have significantly greater research

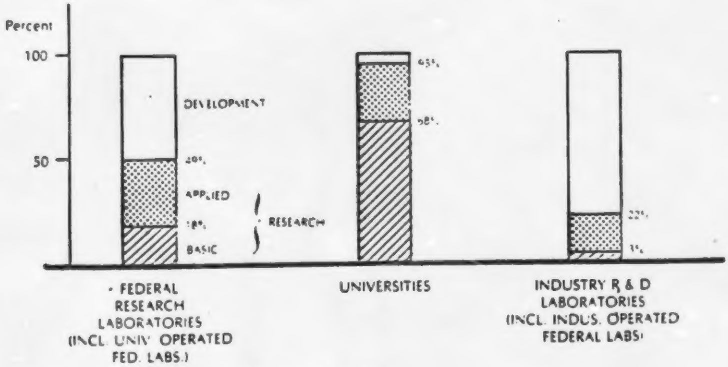
[Exhibit II-8 on the following page]

Exhibit II-8

RELATIVE PERCENTAGE OF SCIENTIST AND ENGINEERS EMPLOYED IN R & D, BY SECTOR



NATURE OF R & D BY SECTOR



SOURCE: National Science Foundation

capabilities. The Federal laboratories have responded to changing environments in different ways, as have industry and the universities. Some laboratories have remained static, while others have changed their charters from their original purposes. The Federal Government must ascertain whether these laboratories are attending to the most relevant activities.

The Federal Government owns more than 700 laboratories. These 700 laboratories vary in size, types of programs and scope of activities. More than 300 have fewer than ten employees and budgets under $300,000 while others have over 2,000 employees with budgets exceeding $200 million.1/

The term "laboratories" used by the Federal Government is a generic term and includes facilities that are actually known as bureaus, centers, facilities, divisions, institutes, activities, offices, museums, stations, research units, or observatories. The Veterans Administration (VA), for example, conducts research in the clinical setting of many of its hospitals, but proper treatment of the patient is their primary function. The U.S. Geological Survey is another case where extensive field offices are necessary to gather and apply data related to their mission. Research for that group is very unlike the work centered around large complex facilities in many defense or space laboratories. Networks of small facilities characterize the National Oceanographic and Atmospheric Administration. Each of these small facilities, including 60 of the VA's clinical research units, is counted separately in the Government's tally of 700 laboratories.

Although it varies greatly from agency to agency, on the average, the Federal laboratories receive about one-half of their sponsoring departments' total R&D funds. About one-half of the R&D funds received by the laboratories are then contracted to universities and industry; the other half is retained by laboratories to carry out roles requiring in-house personnel -- including extensive activities necessary to support contract work. In FY 1983, $10.2 billion of Federal R&D money will be spent on intramural R&D.2/ DOD accounts for $6.0 billion and NASA $1.4 billion. Together they represent 72.5 percent of all intramural R&D.

1/ Federal Laboratory Directory, 1982, Department of Commerce, National Bureau of Standards.

2/ Federal Funds for Research and Development Fiscal Years 1981, 1982 and 1983, National Science Foundation, p. 30.

DOD has 73 laboratories, of which 35 serve the Army, 24 the Navy, and 14 the Air Force. These laboratories employ more than 60,000 people, of which 80 percent are civilian, except the medical and Air Force labs which are 50 percent civilian. The Air Force accounts for 46 percent of DOD's R&D budget. Nearly two-thirds of the annual cash flow is Research, Development, Test and Evaluation (RDT&E) money. The balance of the cash flow comes from procurement funds that are used for the acquisition of initial hardware systems and associated support, particularly product improvements.

NASA operates eight major centers throughout the country. NASA's technical expertise and facilities, such as wind tunnels, are national resources often used by private industry, DOD, the Department of Commerce (DOC), the Department of Energy (DOE), other Federal agencies, and foreign governments. As a result, many of NASA's activities are reimbursed by the using agency. In the FY 1983 budget submission, NASA estimated that 16.5 percent of $1 billion of NASA work will be reimbursable. This work primarily relates to space shuttle operations and space applications.

Methodology

Issue team members interviewed outside advisors as well as 85 key staff members in NASA, the Office of the Secretary of Defense, the Defense Advance Research Projects Agency, former DOD officials, the National Academy of Sciences, the National Science Foundation, the American Association for the Advancement of Science, the General Accounting Office, DOC, Office of Management and Budget (OMB), and other Federal agencies.

Issue team members visited ten DOD laboratories and five NASA centers to gain a better understanding of Federal research facilities and programs. The DOD laboratory site visits included:

- Night Vision and Electro-Optics Lab, Fort Belvoir, VA;
- Mobility Equipment R&D Command Laboratories, Fort Belvoir, VA;
- Harry Diamond Lab, Adelphi, MD;
- Combat Surveillance and TGT-Acquisition Lab, Fort Monmouth, NJ;

- Aviation R&D Laboratories, Moffet Field, CA;
- Naval Medical Research, Bethesda, MD;
- Army Medical Research Institute of Infectious Diseases, Fort Detrick, MD;
- Medical Bioengineering R&D Labs, Fort Detrick, MD;
- Army Institute of Dental Research, Washington, DC; and
- Walter Reed Army Institute of Research, Washington, DC.

NASA installations visited include:

- Goddard Space Flight Center, Greenbelt, MD;
- Langley Research Center, Hampton Bays, VA;
- Ames Research Center, Palo Alto, CA;
- Marshal Space Flight Center, Huntsville, AL; and
- Johnson Space Center, Houston, TX.

Laboratory directors and professional staff members were interviewed during these visits. In addition to these personal contacts, the issue team analyzed numerous relevant published background documents.

Findings

Based on Task Force interviews, laboratory managers support the development of "centers of excellence." The concept of centers of excellence, utilized more and more, involves the concentration of efforts to pursue research in a given area and centrally locate the resources to perform that research. This concept recognizes that some critical mass of resources is required to conduct first-rate research programs. Along the same lines, increased coordination among R&D laboratories has been cited as desirable to avoid excessive program overlap. DOD is emphasizing joint and cross-Service programs to maximize the benefits of R&D investment. An Office of the Assistant for Directed Energy Weapons has been established to coordinate the efforts of the Services and defense agencies in this specific program area. A concerted effort to reduce duplication of effort and enhance productivity is being made.

NASA is already using the concept of centers of excellence. Each center has a specific set of goals, which has permitted the avoidance of nonproductive R&D overlap among centers. Each center concentrates its efforts on specific areas of expertise.

There is no systematic ongoing process for evaluating R&D laboratories. Each Federal laboratory and its sponsoring agency generally have procedures to review and evaluate the efforts in the laboratory on an annual basis. However, these reviews do not generally cover the scope and merit of the science and programs being conducted in the laboratory. DOD, in particular, has experienced problems in this area. Each Service has its own procedure for evaluating R&D programs and laboratories. The Joint Deputies for Laboratories Committee is a notable attempt at an overall evaluation of the laboratories, but most similar efforts have not been totally effective. In a recent review of DOD laboratories conducted by the Under Secretary of Defense for Research and Engineering (USDRE), 3/ the establishment of an effectiveness review process for the laboratories was recommended, reiterating the need for a systematic, ongoing process.

The current method of appropriating laboratory funding has resulted in indecision and uncertainty concerning funding well into the fiscal year for which the funds are needed. As described in R&D 2, R&D Management and the Budget Process, many aspects of the budget process impede effective management of the R&D labs. These problems preclude a normal planning process and have a negative effect on the R&D work of the laboratories. It is highly doubtful that the problem of Congressional delays and dragging out of funding appropriations will go away in the near future. Multiyear procurement by the laboratories of material and services would, however, provide more efficient planning and execution of the R&D process. In addition, more flexibility of the laboratory directors to allocate funds within their laboratories would help alleviate the problem through more efficient management and flexibility of action.

Staffing levels for Federal R&D laboratories have steadily decreased over the past ten years. The DOD Laboratory Management Task Force, composed of a broad array of senior level representatives from within DOD, reported that manpower ceiling reductions have been the greatest single factor negatively affecting the contribution of laboratories over the past 15 years. In the past decade, the Army laboratories were reduced in size by more than one-third, with reductions occurring every year. 4/

3/ Dr. Robert J. Hermann, USDRE Independent Review of DOD Laboratories, March 22, 1982.

4/ DOD, Report of the DOD Laboratory Management Task Force, July 1980.

Most DOD personnel interviewed said that the ceiling on civil service salaries made it difficult to hire or retain top civilian researchers. Federal laboratories report a gradual loss of technical personnel to industry. Furthermore, entry level salaries are not sufficiently competitive with private industry to attract the top college graduates.

A large portion of the Government's aging research facilities have suffered deterioration and are in need of modernization. The current annual investment in facilities and equipment is rapidly becoming inadequate for effective mission performance. Many DOD facilities that the Task Force visited are old and becoming inadequate for current use. Some facilities, which are several decades old but have received reasonable modernization through the years, remain highly useful. Others, however, have become or are becoming marginal in their utility.

The equipment in these facilities is in a similar state. In some instances these tools are merely old. In other instances they are outdated and inadequate, not because of age, but because of the rapid growth of technology and mission requirements.

This was an issue raised by most of the laboratory directors interviewed and noted in published studies. Many DOD laboratories are inadequately equipped primarily because the Services principally fund ongoing, analytical programs and do not make adequate provision for general purpose and technical equipment needs. The outdated equipment in the laboratories is costly to maintain and wastes manpower. As a result, productivity suffers. These facilities and equipment are an essential element of the work environment and as a consequence greatly affect the productivity of the laboratories. Based on Task Force interviews, the decline in facilities could seriously jeopardize the abilities of the laboratories to meet mission challenges. A review of DOD laboratories conducted by USDRE in 1981 concluded that many of the DOD laboratory facilities are substandard, inadequate, obsolete, or energy deficient and need to be updated. 5/

The designation of a facility as a Federal research and development laboratory is broadly and generically applied to a variety of Government-sponsored activities. There are over 700 facilities designated Federal R&D laboratories currently in operation. A number of these facilities are small and engaged in what would be more

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5/ Dr. Robert J. Hermann, *op. cit.*

properly described as data gathering or monitoring functions, not basic or applied R&D. The U.S. Geological Survey, for instance, operates an extensive system of field offices necessary to gather and apply data related to their mission. Another example is the VA, which operates 60 "R&D laboratories," each with ten or more personnel primarily engaged in studying problems arising during the care of veteran patients. These facilities are in sharp contrast to more traditional R&D laboratories. The ten largest laboratories, for instance, each employ a staff of more than 5,000 personnel. Overall only 388 of the 700 R&D laboratories have a staff of ten or more employees. As a portion of the budget, those labs with 100 or fewer personnel account for only 11 percent of the total operating costs for Federal R&D labs (see Exhibit II-9 on the following page).

Federal research and development laboratories are exempt from the provisions of A-76. In the March 29, 1979 version of Circular A-76, R&D was exempted pending development of criteria for determining which R&D work was Governmental and which was commercial activity subject to A-76. The proposed and final revisions exempt R&D entirely from the requirements of the Circular. However, several commercial activities in support of R&D are subject to the provisions of the Circular.

Conclusions

The development of centers of excellence for research should continue. The concentration of resources permits the creation of the critical mass necessary to provide effective research. The trend -- a positive one -- within DOD and NASA is toward more concentration of R&D efforts.

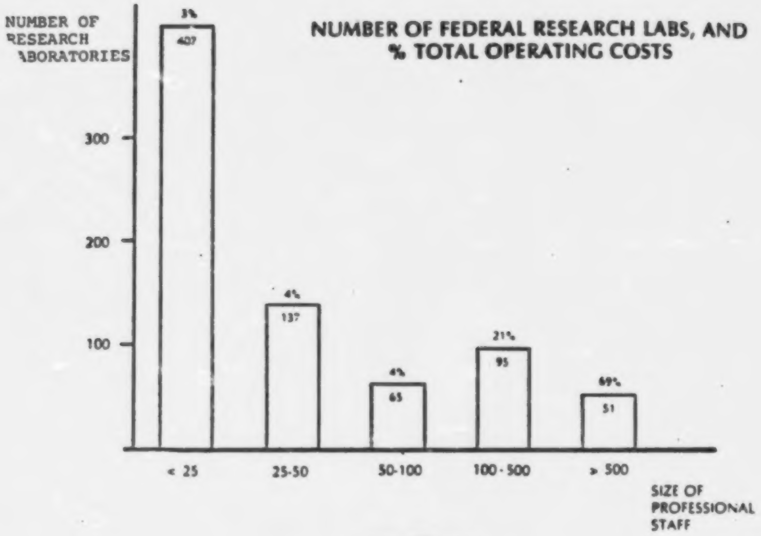
Consideration should be given to consolidating selected Federal R&D laboratories to achieve efficiencies. Based on findings from other PPSS Task Forces, there are R&D laboratories that could benefit from consolidation. This Task Force did not examine this issue in depth and believes that further study is required to determine the potential cost savings and benefits to be derived from consolidating selected Federal R&D laboratories.

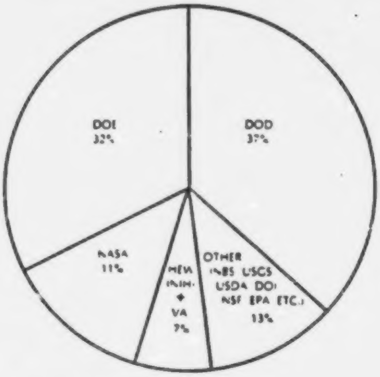
In addition to looking at the laboratories for possible consolidations, the 700 Federal laboratories should

[Exhibit II-9 on the following page]

Exhibit II-9

NUMBER OF FEDERAL RESEARCH LABS, AND % TOTAL OPERATING COSTS





% TOTAL RESEARCH LAB OPERATING COSTS, BY AGENCY

SOURCE: House Appropriations Committee Report, "Utilization of Federal Labs," U.S. GPO, 1978.

be evaluated to determine which ones are actually conducting research and development and classify only those as R&D laboratories. Those facilities that clearly do not conduct actual R&D should be reclassified as to their actual function. This would preclude the broad application of regulations and legislation to facilities with very different sizes, facilities, and missions.

The current exemption of R&D from application of OMB Circular A-76 is not justified. There remain areas of R&D where the private sector would be well suited to conduct work that is now done by Federal laboratories at lower cost. Monitoring and testing functions conducted by many of the small facilities sponsored by the Environmental Protection Agency, National Oceanographic and Atmospheric Administration, U.S. Geological Survey, and others are prime examples of areas where contracting out could save significant amounts of money.

The cost of financing R&D is rapidly increasing for the Federal laboratories as well as for civilian-owned and -operated facilities. The competition for skilled technical personnel and the complexity and sophistication of modern equipment have made R&D, particularly in the areas of high technology, an expensive undertaking. To control these increasing costs, the most effective and efficient management possible must be applied. Many of the overall management problems that affect the R&D labs are covered in R&D 1 and 2 since these issues have a major impact on the labs.

Based on Task Force findings, the overall quality of facilities, equipment and professional staff in the Federal R&D laboratories is declining, while the technology needed to support today's requirements is becoming more costly and sophisticated. Improved management of resources is required to upgrade the quality of facilities and staff.

The current Federal pay schedules significantly handicap the laboratories in recruiting and retaining well-qualified scientists and technicians. Federal pay rates and policies for personnel in the science and engineering disciplines are not comparable with private sector pay for the same level of work.

Any decline in the quality of R&D facilities seriously jeopardizes the ability of laboratories to meet mission challenges. The lack of modernization of many laboratories inhibits work productivity and slows developments. In addition, these facilities are not able to attract and support the highest quality technical personnel. A modernization program geared toward both updating and replacing as well as anticipating future needs should be instituted to address the problems of aging facilities.

Provisions should be made to replace obsolete equipment on a timely basis. Procurement policies should reflect expedient acquisition of state-of-the-art equipment. Replacement of obsolete equipment with more efficient equipment that is less costly to maintain will result in overall cost savings.

Recommendations

R&D 4-1: Additional centers of excellence for R&D research should be formed. Even though many organizations, including NASA, are utilizing this concept to a greater extent, the formation of additional centers of excellence would result in the following benefits:

- more intensive research on given technologies;
- greater purchasing power for sophisticated equipment;
- reduced duplication of work efforts within given technologies; and
- lower administrative and operating costs through better utilzation of resources.

R&D 4-2: The Executive Branch should form a laboratory program evaluation team. To assure a high level of laboratory effectiveness, a systematic approach for program evaluation is necessary. Evaluating laboratory programs periodically will help reduce the amount of money that is wasted on projects that will not result in substantial benefits for the agency. The evaluation team should consist of internal as well as external experts and should perform a limited review of all Federal R&D labs at least once every five years. A more comprehensive review of the larger key labs shoud be conducted every three years. The following areas should be reviewed:

- program overlap;
- laboratory staffing, facilities and equipment;
- mission and research congruency; and
- technical effectiveness of the laboratories.

Each laboratory will continue to be responsible for conducting annual technical reviews. The periodic reviews will provide a comparison among laboratories and will serve as one basis for program and funding decisions.

R&D 4-3: The Executive Branch should undertake a study to examine the potential benefits of consolidating Federal laboratories. Based on Task Force interviews, there is strong evidence that suggests consolidating selected Federal R&D laboratories can result in substantial cost savings. The Task Force currently has insufficient data to recommend specific laboratories that would benefit from consolidation.

R&D 4-4: Directors of Federal R&D laboratories should be given more control over budget appropriations. Less emphasis should be placed on specifying budget items by object code and more flexibility should be given to laboratory directors in determining how the funds will be utilized. The basic objective of increasing directors' control over the use of funds is improved management of resources. The funds can be utilized in those areas that will most benefit the laboratory.

R&D 4-5: Administrative and legislative actions should be initiated to create, at Government-operated laboratories, a scientific/technical personnel system independent of the current Civil Service personnel system. This action would alleviate to some degree the disadvantages now faced by the Government laboratories to attract, retain, and motivate scientific and technical personnel required to fulfill efficiently and effectively their agency-assigned missions.

R&D 4-6: Establish a set of guidelines which would define what constitutes an R&D laboratory. Reclassify those facilities not meeting the guidelines but now included in the list of 700 "laboratories." These guidelines should include requirements that the facility, as its primary activity, be engaged in basic research, applied research, development, or management of R&D. Those organizations which should specifically be excluded from designation as Federal laboratories are those which are engaged primarily in routine quality control and testing, routine service activities, production, mapping and surveys, information dissemination, etc. This reclassification would take facilities now included in the category of R&D laboratories and place them into a more appropriate category such as monitoring station, sampling facility, medical support facility, etc. This reclassification would open the door to more appropriate application of "R&D laboratory" regulations and requirements.

R&D 4-7: Remove current exemption of R&D from the application of the requirements of OMB Circular A-76. In the March 29, 1979 version of the Circular, R&D was exempted pending development of criteria for determining which R&D work was Governmental and which was a commercial activity subject to A-76. The proposed and final revisions exempt R&D entirely from the requirements of the Circular. However, several commercial activities in support of R&D are subject to the Circular's provisions.

Savings and Impact Analysis

The major benefit to be derived from implementing the Task Force recommendations is improved productivity. Based on Task Force interviews with private sector experts, it is estimated that productivity increases of up to 5 percent could be realized. Since the implementation of these recommendations will also incur costs related to the conduct of the evaluations, modernizing facilities, replacing outdated equipment and hiring additional staff at higher salary levels, the Task Force assumes that only approximately 1 percent of actual net savings will be realized on the Federal laboratory budget. Using the FY 1983 figure for intramural research of $10.2 billion, the savings opportunities would be $102 million in the first year.

Removal of the current exemption of Government R&D from application of OMB Circular A-76 would conservatively allow 5 percent of the current laboratory in-house budget to be contracted out. Again using a conservative estimate, a 10 percent savings on the contracted-out work would be realized. Using a base of approximately $10.2 billion as that portion of the laboratory budget spent in-house, $51 million per year could be saved.

The following savings are estimated based on 1983 budget figures and the current Federal laboratory organization. Reclassification of facilities to define as R&D laboratories only those major installations conducting actual R&D would result in a broader application of A-76 and a small increase in savings.

An analysis of potential cost savings is as follows:

	Year 1	Year 2	Year 3	Total
	($ millions)			
Savings resulting from productivity increase	$102.0	$112.2	$123.4	$337.6
Savings resulting from increased use of A-76	51.0	56.1	61.7	168.8
Total savings	$153.0	$168.3	$185.1	$506.4

Implementation

Implementation of R&D 4-1 (centers of excellence), R&D 4-2 (lab evaluation team), and R&D 4-3 (lab consolidation) requires action by the agencies. Congressional action will be necessary to implement R&D 4-4 (lab directors have more control over budget), R&D 4-5 (scientific/technical personnel system), R&D 4-6 (reclassify facilities), and R&D 4-7 (remove A-76 exemption).

II. ISSUE AND RECOMMENDATION SUMMARIES (CONT'D)

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 5: ADMINISTRATION OF RESEARCH GRANTS TO UNIVERSITIES

Issue and Savings

Can changes in the manner in which the Federal Government administers research grants 1/ to universities: (a) improve Government-university relationships; (b) control the increases that have occurred in indirect cost reimbursement; and (c) provide an improved framework for grant administration?

Revision in the negotiating principles for indirect cost reimbursement 2/ and revised grant administration procedures should result in savings opportunities of $117.2 million in the first year, $128.9 million in the second year, and $141.8 million in the third year. Total estimated savings opportunities over three years are $387.9 million. These savings are, in part, based on assumptions of the results of negotiations between the universities and the Government regarding indirect cost rates. Actual savings to be realized would be determined by these parties.

1/ The Task Force recognizes that the Government funding of research conducted by universities is done by grant or contract with the distinction based in the specificity of the scope of the work. For purposes of the discussion of indirect costs, the form of the funding mechanism is not important since the same cost principles apply to both forms.

2/ The President's Private Sector Survey (PPSS) Department of Health and Human Services - Public Health Service, Health Care Financing Administration Task Force identified this as an area for savings opportunities in the National Institutes of Health (NIH). They recommended that reimbursement for indirect cost be reduced by 10 percent. The R&D Task Force also recognizes this as an area with savings potential. Our approach is slightly different.

Background

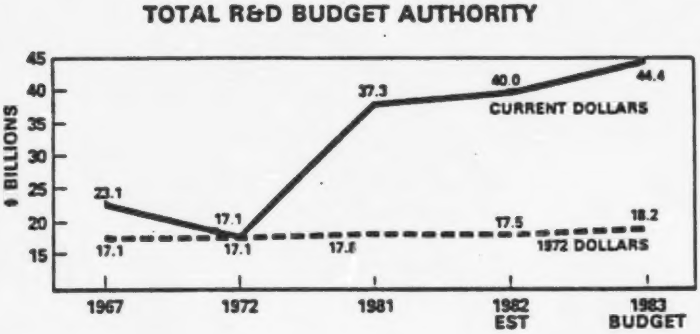
Since the 1940s the United States Government has emphasized a policy of funding basic research performed at universities, thus creating a strong research enterprise. As the level of Federal financial support grew, the relationship between the universities and Government became increasingly complex and symbiotic.

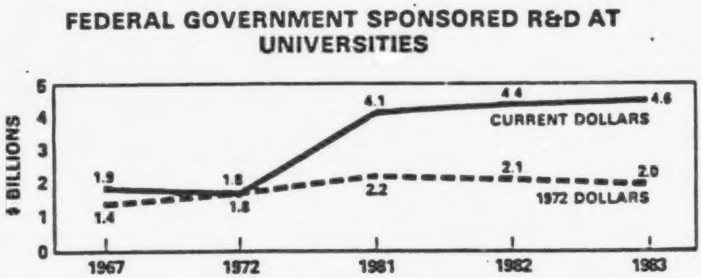
In FY 1983, the level of Federal Government financial support to universities reached $4.7 billion (see Exhibit II-10 on the following page) or about 10 percent of the total Federal research and development (R&D) budget. It continued to account for almost 70 percent of all monies spent on research at universities (see Exhibit II-11). Today, there are approximately 800 colleges and universities conducting Federally sponsored research, 100 of which receive approximately 75 percent of the Federal research funds (see Exhibit II-12).

[Exhibits II-10, II-11 and II-12 on the following pages]

EXHIBIT II-10

Trends in Total Federal R&D Budgets and Federally Supported University Research


TOTAL R&D BUDGET AUTHORITY

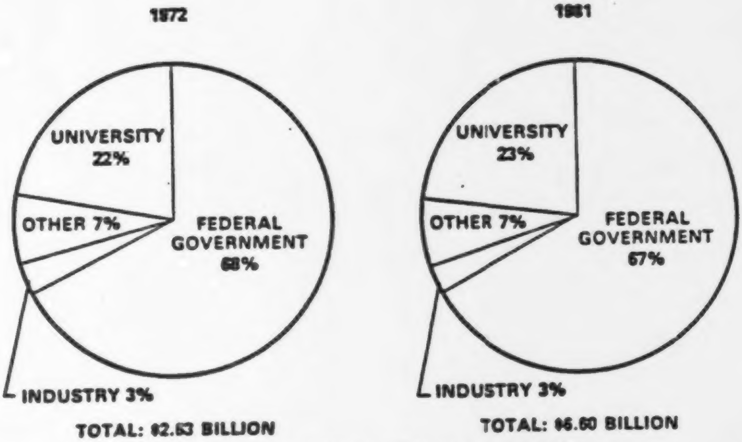

FEDERAL GOVERNMENT SPONSORED R&D AT UNIVERSITIES

Source: Adapted from American Association for the Advancement of Science (AAAS) R&D Report VII, 1982.

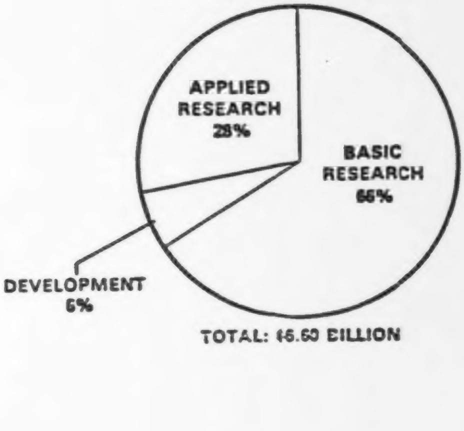
Exhibit II-11

SOURCE OF R&D FUNDING AND TYPE OF
R&D PERFORMED AT UNIVERSITIES

SOURCE OF UNIVERSITY R&D FUNDING



TYPE OF R&D PERFORMED BY UNIVERISITIES



SOURCE: AAAS
R&D REPORT VII,
1982.

EXHIBIT II-12

Federal Obligations for Research & Development to the 100 Universities and Colleges Receiving the Largest Amounts, By Agency: FY'80 (dollars in thousands)

RANK	INSTITUTION (RANKED BY AMOUNT RECEIVED)	TOTAL	USDA	COM	DOD	ED	DOE	EPA	HHS	INT	NASA	NSF	OTHER*
	TOTAL, ALL INSTITUTIONS	4,155,366	211,809	50,012	555,919	48,022	279,367	76,717	2,025,640	38,750	161,293	607,615	100,022
1	JOHNS HOPKINS UNIVERSITY	239,869	376	330	163,490	668	3,382	1,483	64,459	100	1,260	3,919	652
2	MASS INST OF TECHNOLOGY	141,011	280	2,136	26,859	126	49,138	934	25,163	538	9,904	24,670	1,267
3	STANFORD UNIVERSITY	106,539	305	71	19,567	455	4,763	816	48,069	482	7,160	22,272	999
4	UNIVERSITY OF WASHINGTON	100,567	761	4,083	13,249	2,551	4,365	293	57,727	510	2,202	13,931	695
5	UNIV OF CAL SAN DIEGO	90,703	35	75	11,703	239	1,293	169	32,752	60	9,668	34,739	0
6	UNIV OF CAL LOS ANGELES	87,073	431	143	4,650	1,500	8,976	764	57,459	87	2,715	10,169	179
7	HARVARD UNIVERSITY	83,997	400	303	6,007	176	2,359	1,772	57,987	99	4,079	10,456	359
8	COLUMBIA UNIV MAIN DIV	81,361	0	536	5,250	125	4,106	188	67,846	0	2,005	15,219	6,088
9	UNIV OF WIS-MADISON	80,460	5,201	0	3,797	2,660	7,270	1,088	41,549	275	4,136	14,233	271
10	CORNELL UNIVERSITY	74,761	5,956	18	4,204	16	2,571	1,282	31,391	506	3,161	26,933	1,725
	TOTAL 1ST 10 INSTITUTIONS	1,084,361	13,685	7,691	258,776	8,310	88,403	8,769	464,402	2,637	45,290	176,543	11,835
11	UNIVERSITY OF MINNESOTA	74,739	5,632	610	1,362	1,543	3,133	1,812	49,706	507	1,789	8,379	266
12	UNIVERSITY OF MICHIGAN	71,206	298	2,470	3,051	1,120	3,596	2,359	40,464	0	4,206	10,938	2,706
13	UNIV OF PENNSYLVANIA	70,843	125	226	5,232	623	2,064	349	51,129	15	237	9,106	1,927
14	YALE UNIVERSITY	67,970	130	39	3,840	0	5,128	84	51,423	0	319	7,007	0
15	UNIV OF CAL SAN FRANCISCO	62,581	0	0	330	451	3,250	0	56,756	0	404	1,390	0
16	WASHINGTON UNIVERSITY	52,512	70	50	1,289	0	981	559	45,298	22	1,426	2,803	16
17	UNIVERSITY OF CHICAGO	50,592	135	80	643	556	2,098	0	32,740	0	4,603	9,637	100
18	UNIV OF ILL URBANA	50,332	5,105	0	6,828	2,086	5,680	1,152	9,933	417	1,253	16,611	1,267
19	UNIV OF CAL BERKELEY	49,963	1,841	98	7,890	883	1,763	497	16,098	739	4,310	15,085	760
20	PENNSYLVANIA STATE UNIV	48,279	9,465	444	16,994	6	4,511	455	12,488	1,026	1,646	4,701	545
	TOTAL 1ST 20 INSTITUTIONS	1,683,336	32,496	11,708	306,235	15,375	120,985	16,036	830,437	5,363	65,479	260,300	19,432
21	UNIV OF SOUTHERN CAL	48,198	0	195	11,967	3	1,030	959	27,964	275	1,585	4,839	381
22	UNIVERSITY OF COLORADO	46,460	160	2,931	1,961	1,373	3,399	245	25,461	41	3,356	5,201	376
23	DUKE UNIVERSITY	42,531	139	315	1,727	60	1,220	596	34,759	0	162	3,513	60
24	UNIV OF CAL DAVIS	42,111	4,245	0	676	162	3,886	2,040	16,210	916	123	3,945	12,5[illegible]
25	UNIV OF NC AT CHAPEL HILL	41,850	365	0	793	960	513	1,909	27,596	267	0	3,536	6,[illegible]
26	UNIVERSITY OF ROCHESTER	40,992	60	0	1,769	0	6,921	6	26,258	0	127	3,851	0
27	YESHIVA UNIVERSITY	40,252	0	0	95	155	0	0	39,056	0	0	946	0
28	UNIV OF TEXAS AT AUSTIN	40,223	176	0	15,175	62	5,397	222	7,786	377	3,851	7,319	188
29	NEW YORK UNIVERSITY	39,696	105	0	1,876	651	2,919	850	28,037	41	576	4,629	10
30	OHIO STATE UNIVERSITY	37,036	5,082	[illegible]3	3,836	1,041	1,347	1,745	12,532	419	1,407	4,906	4,350
	TOTAL 1ST 30 INSTITUTIONS	2,100,481	42,808	15,522	349,488	19,162	169,217	24,208	1,076,092	7,177	76,664	302,683	43,460
31	PURDUE UNIVERSITY	36,487	4,720	0	2,023	112	4,156	268	10,216	600	3,457	8,936	2,001
32	UNIVERSITY OF IOWA	36,598	0	0	1,190	465	748	652	26,197	0	3,615	2,231	0
33	CALIFORNIA INST OF TECH	36,493	8	231	5,640	0	3,618	323	7,212	646	5,286	11,456	77
34	UNIVERSITY OF ARIZONA	33,283	2,419	427	4,331	15	1,463	549	12,716	862	3,399	5,448	1,476
35	UNIVERSITY OF PITTSBURGH	33,181	105	130	2,423	228	1,590	899	22,680	281	948	3,745	152
36	UNIVERSITY OF UTAH	31,828	62	0	1,426	0	3,639	198	20,450	697	918	4,252	186
37	BAYLOR COL OF MEDICINE	31,784	792	72	206	2,951	0	382	27,306	0	257	218	0
38	NORTHWESTERN UNIVERSITY	31,722	100	165	3,297	1,601	1,465	0	15,795	43	222	7,029	2,005
39	CASE WESTERN RESERVE UNIV	31,399	0	242	2,539	300	919	14	22,116	0	1,573	3,614	82
40	OREGON STATE UNIVERSITY	29,577	5,466	4,209	2,399	0	1,054	1,432	5,170	293	800	7,776	976
	TOTAL 1ST 40 INSTITUTIONS	2,428,833	56,480	20,998	370,962	24,636	187,349	28,925	1,243,966	10,599	97,137	357,586	50,417
41	MICHIGAN STATE UNIVERSITY	28,777	5,258	0	1,022	1,803	1,728	1,392	9,777	656	603	6,346	392
42	UNIVERSITY OF MIAMI	27,986	0	50	2,303	98	872	1,933	17,485	10	500	4,725	10
43	GEORGIA INSTITUTE OF TECH	27,833	12	89	19,929	0	1,579	139	1,650	319	1,382	2,217	521
44	TEXAS A & M UNIVERSITY	26,924	7,220	313	3,621	0	1,657	4,333	2,892	999	1,652	5,249	388
45	UNIV ALABAMA BIRMINGHAM	26,835	0	0	168	573	0	0	25,618	0	65	411	0
46	UNIV OF MD COLLEGE PARK	26,367	3,333	598	4,958	226	3,996	579	1,516	158	3,916	7,300	239
47	INDIANA UNIVERSITY	26,336	129	0	908	631	1,164	103	15,344	17	283	7,577	358
48	VANDERBILT UNIVERSITY	25,928	0	0	136	126	335	71	22,286	97	101	1,605	173
49	UNIVERSITY OF FLORIDA	25,136	4,896	98	2,103	153	965	1,125	10,375	221	737	2,765	728
50	BOSTON UNIVERSITY	24,909	0	39	2,049	195	187	84	20,275	0	298	1,682	100
	TOTAL 1ST 50 INSTITUTIONS	2,695,860	77,326	32,181	406,759	28,037	179,792	38,634	1,372,162	12,676	106,474	398,663	53,376

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EXHIBIT II-12 (CONT'D)

RANK	INSTITUTION (RANKED BY AMOUNT RECEIVED)	TOTAL	USDA	COM	DOD	ED	DOE	EPA	HHS	INT	NASA	NSF	OTHER*
51	ALBANY STATE COLLEGE	24,024	0	0	0	0	0	0	0	0	0	24	24,000
52	UNIV OF HAWAII-MANOA	23,677	804	0	2,904	0	6,106	943	5,618	293	3,390	4,079	0
53	WOODS HOLE OCNGRPHIC INST	23,619	0	0	8,111	0	1,192	73	0	570	307	13,365	0
54	UNIVERSITY OF VIRGINIA	23,204	350	93	1,458	1,795	2,411	78	13,161	77	481	3,296	376
55	U TEX HLTH SCI CTR DALLAS	22,173	0	0	0	0	0	0	21,929	0	41	203	0
56	COLORADO STATE UNIVERSITY	21,976	4,221	240	2,646	0	1,279	1,299	5,720	1,043	1,152	4,163	63
57	CARNEGIE-MELLON UNIV	21,861	0	0	8,411	132	4,608	136	2,276	382	425	5,416	87
58	CUNY MT SINAI SCH OF MED	21,799	0	0	4	0	0	31	21,037	0	0	472	255
59	UNIVERSITY OF KANSAS	21,738	194	91	997	1,991	103	0	15,776	0	1,442	1,506	371
60	PRINCETON UNIVERSITY	21,423	0	657	2,714	0	2,924	0	5,071	0	1,381	6,702	64
	TOTAL 1ST 60 INSTITUTIONS	2,921,359	82,695	23,151	433,964	31,948	198,695	40,786	1,462,398	15,034	119,828	438,448	78,992
61	U TENNESSEE KNOXVILLE	20,972	3,796	90	1,723	50	9,519	91	3,360	45	659	1,233	62
62	UNIV OF TEX CANCER CENTER	20,345	0	0	0	0	0	0	20,098	0	0	247	0
63	ROCKEFELLER UNIVERSITY	19,511	109	0	163	42	731	0	16,330	0	107	2,052	0
64	UNIVERSITY OF CINCINNATI	19,422	140	0	936	0	381	2,243	13,810	71	265	1,468	0
65	LOUISIANA STATE UNIV	19,100	3,132	1,902	1,111	0	1,441	280	9,339	287	201	1,107	0
66	UNIVERSITY OF CONNECTICUT	18,911	779	0	906	0	980	194	14,267	242	246	1,739	6
67	UNIV OF CAL IRVINE	18,476	104	0	2,238	0	2,336	124	9,887	0	248	3,287	198
68	SUNY AT BUFFALO	18,265	0	373	101	0	703	0	13,575	0	66	3,261	186
69	SUNY AT STONY BROOK	18,240	0	0	257	0	1,670	75	9,505	0	857	5,866	132
70	UNIV OF ALASKA FAIRBANKS	17,908	1,267	0	8,447	15	1,079	465	140	614	1,187	4,896	0
	TOTAL 1ST 70 INSTITUTIONS	3,111,859	92,018	25,476	449,474	32,056	216,896	44,219	1,572,989	16,047	119,944	463,676	79,194
71	UNIVERSITY OF NEW MEXICO	17,863	80	77	5,068	441	1,926	0	8,068	9	260	1,153	0
72	UNIV OF MD BALT PROF SCH	17,171	3	76	619	0	166	225	15,613	0	0	491	0
73	UNIVERSITY OF GEORGIA	16,809	5,365	66	483	0	2,140	640	3,951	220	107	3,637	388
74	VA POLYTECH INST & ST U	16,711	3,946	39	2,287	47	3,491	548	1,220	700	2,179	2,900	356
75	UNIV OF MISSOURI COLUMBIA	16,380	5,352	25	871	76	354	635	6,887	225	286	1,609	0
76	RUTGERS THE ST UNIV OF NJ	16,130	2,556	26	766	7	307	132	7,279	107	113	4,330	527
77	N C STATE UNIV AT RALEIGH	16,059	5,962	95	911	0	1,602	1,367	2,207	832	900	2,940	0
78	EMORY UNIVERSITY	16,028	0	0	103	1,118	115	206	14,077	0	150	259	0
79	VIRGINIA COMMONWLTH UNIV	15,575	3	0	144	104	122	943	14,136	0	72	319	130
80	BROWN UNIVERSITY	15,336	0	44	1,434	0	1,730	0	5,537	35	698	5,766	100
	TOTAL 1ST 80 INSTITUTIONS	3,275,996	115,265	25,962	462,864	33,851	227,787	48,310	1,651,964	18,273	124,389	486,696	80,653
81	UNIVERSITY OF DAYTON	15,316	0	0	14,163	0	373	317	64	0	417	0	0
82	TEMPLE UNIVERSITY	15,217	51	0	110	632	165	173	12,983	5	25	808	185
83	UNIV OF MASS AT AMHERST	14,146	1,874	65	1,748	0	469	921	3,021	213	376	5,879	0
84	UNIVERSITY OF KENTUCKY	13,933	6,867	103	338	175	983	622	3,065	990	252	1,026	330
85	GEORGE WASHINGTON UNIV	13,608	101	30	2,960	1,083	875	389	6,207	0	1,188	836	19
86	GEORGETOWN UNIVERSITY	13,489	86	0	2,035	0	2,271	455	8,050	0	30	319	43
87	WASHINGTON STATE UNIV	13,162	4,081	125	719	0	416	638	2,996	446	155	1,941	1,425
88	UNIV OF RHODE ISLAND	12,907	918	4,048	1,119	20	178	1,418	1,060	73	73	3,969	61
89	UNIV OF VT & ST AGRIC COL	12,035	1,304	0	70	97	368	71	9,616	54	100	438	0
90	UNIV OF ILL MED CTR CHGO	12,017	0	0	0	0	0	173	11,625	0	0	219	0
	TOTAL 1ST 90 INSTITUTIONS	3,411,022	128,544	30,305	486,106	35,853	233,287	52,807	1,722,440	20,274	127,157	502,429	82,924
91	U TEX MED BRNCH GALVESTON	11,904	0	0	257	150	0	529	10,304	0	331	283	90
92	WAYNE STATE UNIVERSITY	11,900	0	0	865	0	387	86	8,202	0	76	2,022	294
93	U TEX HLTH SCI CTR HOUSTN	11,282	0	0	52	0	102	760	9,927	0	8	433	0
94	U TEX HLTH SCI CTR S ANTO	11,153	0	0	0	0	0	0	10,984	0	50	119	0
95	UNIV OF CAL SANTA BARBARA	10,946	31	0	1,328	110	812	761	2,631	0	981	4,686	0
96	NEW MEXICO STATE UNIV	10,486	1,529	0	2,672	333	1,715	0	574	691	1,546	998	88
97	SYRACUSE UNIVERSITY	10,263	246	32	3,561	240	212	115	2,927	136	130	2,486	0
98	IOWA ST U OF SCI & TECH	9,913	5,033	0	533	0	109	471	1,336	143	379	1,598	289
99	DARTMOUTH COLLEGE	9,814	26	0	262	0	106	95	7,617	0	240	1,361	140
100	TUFTS UNIVERSITY	9,812	700	0	238	0	455	7	7,857	0	153	402	0
	TOTAL 1ST 100 INSTITUTIONS	3,519,293	136,115	30,337	496,074	36,786	237,383	55,988	1,774,799	21,098	130,649	516,311	83,393

[illegible]

Since World War II, Government agencies have used a variety of mechanisms to promote high quality basic research. NIH, for example, was among the first to provide funds to biomedical research. NIH developed a Peer Review System to reach decisions on funding grant applications based upon the highest scientific merit. Under this system, grant applications and results were evaluated by independent researchers familiar with the subject area of the grant in question. The National Science Foundation (NSF) modified NIH's Peer Review System for use in its grant programs. Other agencies, such as the Department of Defense (DOD), extended their existing contract mechanisms to sponsor university research but did not adopt the NIH Peer Review model.

Initially, most award systems appeared to work fairly well; Federal funds were available and competition for funds was not as intense as in recent years. Currently, however, Federal support of university research has actually declined when considered in terms of constant dollars. Furthermore, universities have experienced deteriorating financial positions due to declining enrollments, shrinking endowments, and escalating operating costs.

The financial constraints on both the Government and the universities, as well as differences in goals, have sometimes created controversy and conflicts between the universities and the Government. For example, university desires for flexibility and independence in the performance of research are often difficult to integrate with the Government's need for effective cost reimbursement and accounting procedures.

The Government has attempted to streamline financial reporting requirements for universities through issuance and revision of the Office of Management and Budget (OMB) Circulars A-21 ("Cost Principles for Educational Institutions") and A-110 ("Grants and Agreements With Institutions of Higher Education, Hospitals, and Other Nonprofit Organizations"), among others. Nevertheless, grant accounting and administration have remained relatively complex for a number of reasons, including the Government's need to ensure public accountability and the financial pressures on universities to recoup all of the indirect costs associated with research.

Methodology

The Task Force focused its detailed review for this issue on the research grant activity of three Federal agencies: NSF, NIH and the Office of Naval Research (ONR) in DOD. These three agencies were selected because they fund about 65 percent of all Federally funded research performed at universities today (see Exhibit II-13 on the following page).

Although the Task Force's in-depth analysis concentrated on these agencies to obtain a more complete understanding of R&D Government-wide, the Task Force reviewed reports of, and conducted interviews in, several other agencies, including:

- o White House Office of Science and Technology Policy (OSTP),
- o OMB,
- o General Accounting Office (GAO), and
- o Department of Commerce (DOC).

These discussions and additional analyses of previous studies resulted in a set of preliminary issues that were developed in outline and questionnaire form. These issues were used in follow-up conversations with officials from the University Council on Government Relations (COGR) and the National Academy of Sciences (NAS). The issues were then refined and served as the basis for visits to nine major universities, which together receive about 25 percent of total Federal funds for university research. The issue team interviewed university administrators, department chairpersons and faculty researchers during campus visits.

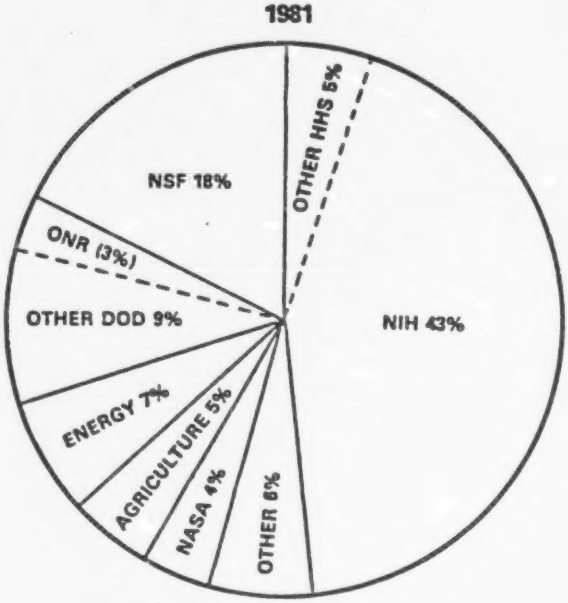
The universities were selected on the basis of their: (a) representation among both public and private institutions, (b) geographic distribution, (c) varying indirect cost rates, (d) difference in cognizant audit agency [Health and Human Services (HHS) or DOD], and (e) difference in Federal funding patterns (i.e., different funding source among NIH, NSF, DOD, Department of Energy, National Aeronautics and Space Administration, and Department of Agriculture). Universities visited were:

- o Harvard University,
- o Massachusetts Institute of Technology,
- o University of North Carolina,
- o University of Michigan,
- o University of Illinois,
- o Northwestern University,
- o University of Minnesota,
- o Stanford University, and
- o University of California.

[Exhibit II-13 on the following page]

EXHIBIT II-13

DISTRIBUTION OF UNIVERSITY R&D SUPPORT AMONG MAJOR FEDERAL AGENCIES



Source: AAAS R&D REPORT VII, 1982.

Findings

The subject of indirect cost recovery is a major source of controversy between the universities and the Federal Government. Although the controversy has heightened in recent years because of attempts by various Federal agencies to control the growth of the rates, its origin goes back to the basic principles involved in calculating indirect costs.

OMB Circular A-21 sets forth the basic principles to be used in determining indirect costs. This Circular has evolved based on the active participation of the universities and the Federal Government. The issue that has been the most troublesome is the calculation of the labor-based indirect cost pools, particularly departmental administration. This cost pool is determined based on a system of payroll distribution, which can take several forms, including:

- a planned, budgeted, or assigned allocation of effort, which is documented and confirmed after the fact;
- an after-the-fact activity record; and
- multiple confirmation records.

Each university applies these principles in a slightly different manner based on its own institutional structure and accounting practices. The following table presents the average indirect cost rate and its components for all universities under the cognizance of HHS.[3]

Average Indirect Cost Rate as a Percent of Direct Cost

Operation and Maintenance	11.7%
Departmental Administration	14.5
Sponsored Project Administration	3.0
General and Administration	7.3
Library	1.9
Depreciation/Use Allowance	4.2
Student Services	0.3
Carry Forward	0.7
Total	43.6

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[3] The Federal Government uses the single audit concept for universities. Responsibilty for approval and audit of the indirect rate for any one university is assigned either to HHS or ONR as the cognizant agency.

As shown above, the largest indirect cost component is departmental administration, which accounts for time spent in institutional administration, committees and other miscellaneous institutional activities. This is also the most contentious component.

The universities have incurred an increased burden in setting up systems to account for the indirect costs. A 1980 report by the University of California 4/ estimated the cost of complying with OMB Circular A-21 at $900 per award. Other universities which receive $10 to $20 million in grants each year report staffs of three to six people devoted to maintaining the effort reporting system with upwards of 20 people involved in grant administration.

The indirect cost rates that result from the application of the Circular have been increasing in the 1972-1982 time frame as shown in Table II-1 on the following page. In 1972 the average indirect rate as measured as a percentage of direct costs was 25.9 percent. By 1982 the rate had grown to 42.8 percent 5/, a 65 percent increase. Seventy-five percent of this increase occurred in the first half of the period covered (1972-1977) and although the rate of increase has declined in the later half (1977-1982), it is still increasing.

[Table II-1 on the following page]

4/ The University of California, Partnership Between Universities and the Federal Government, January 14, 1980.

5/ The figure used here differs from the 43.6 percent rate shown in the previous table primarily because of the different base to which it is applied. The 42.8 percent is derived by adding the total indirect cost awards to each NIH grant and dividing by the total cost. The 43.6 percent figure applies only to the universities under HHS cognizance (approximately 90 percent) and is weighted on the basis of the total research program of those universities.

Table II-1

HISTORY OF INDIRECT COST RATES PAID BY NIH

	DIRECT COST	INDIRECT COST	TOTAL COST	INDIRECT COST RATE*
72	$ 641,865	$ 166,243	$ 808,108	25.9
73	614,078	185,587	799,665	30.2
74	745,547	240,191	985,738	32.2
75	741,558	258,938	1,000,496	34.9
76**	1,058,466	386,164	1,444,630	36.5
77	961,162	359,140	1,320,302	37.4
78	1,112,973	416,093	1,529,066	37.4
79	1,331,722	512,279	1,844,001	38.5
80	1,463,768	586,306	2,050,074	40.0
81	1,568,995	655,143	2,224,138	41.8
82	1,610,679	689,855	2,300,534	42.8

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* Indirect Cost Rate measured on the basis of the ratio of indirect costs to direct costs.

** Includes the quarter (7/76-9/76) involved in the transition from the July 1 - June 30 fiscal year to the October 1 - September 30 fiscal year.

There are basically three causes for this growth.

- the initiation of indirect cost accounting systems by the universities, as they shifted away from the flat rates that were prevalent in the 1960s (these systems provide for improved identification of costs to be included in the indirect pool);
- inflation in certain components of indirect cost which is in excess of the inflation in payroll (e.g., energy cost); and
- a more liberal interpretation of the guidelines which have expanded the indirect cost base.

There has been increasing recognition of this growth in indirect costs, and pressure is growing to control the growth. (The growth in the indirect cost rate is affecting NIH and NSF more than the other agencies since a large percent of their total budget, approximately 75 percent for each agency, is composed of university research grants.) NIH proposed to reduce the reimbursement for indirect costs by 10 percent in FY 1983, but Congress rejected the proposal. The House Committee on Appropriations requested a report on the indirect cost of biochemical and biomedical research from HHS. The report recommended the establishment of a fixed allowance tailored to each institution's historical level.

The reason for the pressure on NIH to control the indirect costs can be seen from Table II-2, on the following page, which shows the average cost of NIH grants in constant dollars from FY 1970 to FY 1982. It was extracted from the report to the House Appropriation Committee. Average indirect costs have increased over the time frame and average direct costs have decreased, particularly since 1972. More and more of the average grant amount is being absorbed by indirect costs. As shown in the last column of the table, the ratio of indirect cost to direct cost has increased from 28.4 percent in 1970 to 44.0 percent in 1982, a 55 percent increase in the rate.

New funding mechanisms and grant administration procedures designed to create more academic institutional flexibility, stability, responsibility and accountability are being evaluated and implemented by NIH, NSF and ONR. Examples include the following:

- NSF has "redefined" its grant relationship with universities to permit greater flexibility in grant management. Differences between old and

[Table II-2 on following page]

Table II-2

TRENDS IN AVERAGE AMOUNT AWARDED FOR NIH TRADITIONAL RESEARCH PROJECT GRANTS FISCAL YEARS 1970-1982 IN TERMS OF 1970 DOLLARS

FISCAL YEAR	TOTAL COSTS - CONSTANT DOLLARS	DIRECT COST - CONSTANT DOLLARS	INDIRECT COST - CONSTANT DOLLARS	INDIRECT COST AS A PERCENT OF DIRECT COST
1970	$36,894	$28,740	$ 8,154	28.4%
1971	39,497	30,395	9,102	29.9
1972	41,817	31,657	10,160	32.1
1973	42,272	31,561	10,711	33.9
1974	44,186	32,781	11,405	34.8
1975	40,890	30,242	10,648	35.2
1976	40,666	29,576	11,090	37.5
1977	42,394	30,757	11,637	37.8
1978	42,889	30,937	11,952	38.6
1979	42,243	30,204	12,039	39.9
1980	41,778	29,619	12,159	41.0
1981	41,651	29,271	12,380	42.3
1982	41,986	29,144	12,842	44.0

Note: Supplements to prior-year awards are excluded in the computation of the average dollars. Constant dollars are based on the biomedical R&D price deflators (FY 1970 = 100). The transition quarter (TQ) which recurred between the end of FY 1976 and the beginning of FY 1977 is excluded. Unobligated balances are distributed between direct and indirect costs.

new procedures are shown in Exhibit II-14 on the following page.

- NIH is experimenting with Fixed Obligation Grants (FOGs) and has redefined administrative relationships with grantees in a manner similar to NSF, as discussed above. Under FOGs, once the funding agency has made a tentative decision to make a particular award (e.g., the applicant has completed the current application and peer review procedures), the agency and the prospective performer engage in preaward negotiations to establish agreement on the following: (1) the objectives of the project, (2) the nature and frequency of the technical reports that the performer is to furnish the sponsor as evidence of progress, and (3) the amount and period of the award.

  If these negotiations are successful, the sponsor makes the award without any additional requirements for reporting. The sponsor would rely exclusively upon the technical reports to assess whether the performer's accomplishments under the project constitute an acceptable return. Failure by the performer to achieve the mutually agreed upon objectives would weigh negatively in the sponsor's considerations about future funding for that performer's activities, but would not require the withdrawal or return of funds already awarded -- hence the name "Fixed-Obligation Grant."[6]

- ONR is experimenting with a Total Business System Review (TBSR) approach that analyzes an institution's financial resources and business management policies. The TBSR emphasizes business management systems review, audit and monitoring rather than grant-by-grant transactions.

[Exhibit II-14 on the following page]

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[6] HHS, NIH, Advisory Committee to the Director. Costs for Biomedical Research, Proposed Changes in NIH Authorization and Operations and a Proposal for the Fixed Obligation Grant. Washington, October 1981.

Exhibit II-14

DIFFERENCES RESULTING FROM NSF'S REDEFINITION OF GRANT PROCEDURES

	Does the University Have the Authority to Make the Subject Changes Under:	
Type of Change	Old Procedures	New Procedures
Adjust dollars among budget line items	Yes, except 125% or $500 limit on domestic travel	Yes, without regard to percent or dollars
Approve foreign travel	No	Yes
Approve all permanent equipment purchases	No	Yes
Cover pre-award costs	No	Yes, up to 90 days at grantee risk
Allocate funds among related projects	No	Yes
Allow-no-cost extensions	No	Yes, one time up to six months
Contract for project effort	No	Yes
Change principal investigator	No	No
Change scope	No	No

Source: R.D. Newton, Redefining the NSF-University Grant Relationship, NSF, September 1982.

- NIH and NSF are placing increasing emphasis on multiyear funding of grants in order to achieve greater research program stability. The average NIH grant is for a period greater than three years, and in FY 1982, 20 percent of the grants were for five years. In FY 1982, for the first time, NSF had more multiyear grants than one-year grants.

Conclusions

The Government-university relationship is strained by external and internal factors that inhibit the effective performance of basic research. The current environment is not optimal for attaining either party's mission and goals.

The increased tension associated with the indirect cost question is counterproductive. The time devoted to the question by senior university administrators and senior Government officials is totally unwarranted and is detrimental to their leadership functions. A method should be found to permit the indirect cost to be handled at lower levels in the organization.

New funding mechanisms and recent changes in Government policies are having a positive impact on the conduct and management of university research. The programs listed in the Findings section demonstrate that Federal agencies are making initiatives toward improving the Government-university relationship. Our interviews indicated that these innovative approaches can result in a better grants administration process. NSF's redefined grant program, in particular, has been well received by the universities and the Government.

Recommendations

R&D 5-1: The cognizant agencies should negotiate indirect cost rates that include a fixed rate for the administrative components and relieve the universities of the main portion of the burden associated with effort reporting.

The administrative components of the indirect cost rate (departmental administration, general and administration, and sponsored project administration) are the most difficult components to establish on the basis of documented, objective evidence and further attempts to reach a compromise on acceptable forms of documentation will only create more friction and frustration. Instead fixed rates should be negotiated and the ongoing requirements for documentation of actual rates should be eliminated.

Such an approach should benefit the universities in that it reduces the burden on them and gives them a definite target toward which to manage. To the extent that their actual administrative expenses are less than the negotiated amount, they would benefit. If the actual expenses cannot be controlled within the target, they will have to make up the differences.

The Federal agencies would also benefit because this would help to eliminate the most contentious element in the management of the grant programs. Also to the extent that increases in the administrative components are the cause in the growth of indirect rates, it could be better controlled in this manner.

In operation it would be desirable to establish one rate nationwide. Such a rate would be applied to all universities and would greatly simplify grant administration and record-keeping. This approach may be difficult to implement initially with such a diverse group. As an alternative, it should be possible to negotiate a fixed rate with each university which should be considerably below the current rate since the burdens associated with the documentation of the rate would be eliminated.[7/]

R&D 5-2: OMB should encourage agencies to implement new funding mechanisms and grant administration procedures.

The issue team recommends that NSF, NIH, DOD, and other Federal agencies continue examining alternative funding mechanisms and grant administration procedures. The most promising programs at an agency should be examined by other agencies for applicability to their own research grants and contracts. OMB should provide this coordination. Greater agency coordination and cooperation is needed to share improvements in Federal support mechanisms. It is recommended that:

- All Federal agencies supporting university research experiment with the NSF redefined grant concept during the next fiscal year. The NSF redefined grant program permits limited grouping of scientifically related projects, allows the university to make certain specified types of budgetary changes on its own, and streamlines grant administration. After each agency's eval-

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[7/] We recognize that all of the burden associated with indirect cost would not be eliminated. However, since the accounting for departmental administration is supposed to be the most burdensome, the burden would be considerably reduced.

uation shows adequate university accountability practices, a Government-wide program can be implemented. This program will result in cost-effective university research management and increased researcher productivity.

- NSF and NIH evaluate the ONR short-form research contract approach and adapt it to selected small (e.g., less than $50,000) programs within the next year. The short-form contract streamlines and accelerates research contract award, thereby reducing administrative costs to both the Government and universities. NIH and NSF should evaluate whether ONR's short form can be used with their peer review systems or if an internal review process is more cost-effective.

- All agencies funding university research develop quantifiable goals within the next fiscal year for increased use of multiyear grants. These goals should be explicitly stated in annual budget materials. This activity will improve the stability of ongoing research efforts and encourage the longer term research investigations of more complex problems which may not be amenable to near-term solutions.

- HHS conduct an evaluation of the TBSR being implemented by ONR. TBSR provides oversight consistent with the trend of transferring more responsibility for research grant administration to the institutions. HHS should determine if TBSR could encourage greater research effectiveness without loss of accountability in health research.

R&D 5-3: OMB should develop a simplified, optional method for determining indirect rates for institutions receiving less than $10 million annually.

OMB should work with HHS and ONR to develop and test a simplified method of institutional reporting for universities receiving between $3 million and $10 million in Federal research support each year. Currently, OMB Circular A-21 provides a simplified method for determining indirect rates for universities receiving less than $3 million in Federally sponsored research grants. No such option is available to the universities receiving between $3 million and $10 million. Savings in administrative time could be achieved for both universities and the Government without serious degradation of the information needed for program management. Although there are about 700 universities (88 percent) with less than $10 million a year in research funds, they receive only 20 percent of this total.

Savings and Impact Analysis

The Government has invested more than $100 billion in universities during the past 35 years to build the world's finest basic research enterprise. The technological prominence that the United States gained as a result of this investment must be safeguarded. Recent years have been characterized by minimal real growth or actual decline in support of university research. The Task Force believes that attention should be focused on how to optimize the conduct of research through improvements in environment, systems and research management rather than by reducing funding for R&D.

A savings and impact analysis for each recommendation follows:

R&D 5-1: It is anticipated that the negotiation of the administrative components would result in lower costs to the Government for the existing base of university research. The reduction in the university burden associated with the documentation of departmental administration and the elimination of that controversial part or the problem should result in a lower average rate.

There is no basis to predict the actual reduction that would occur in the indirect rate when the recommendations are implemented. The rates to be set are to be negotiated between the universities and the Government and the results of these negotiations cannot be anticipated. In order to compute savings, it will be assumed that the administrative components would be reduced an average of 3 percent. The 3 percent assumption is based on a reduced burden associated with effort reporting, a reduction in other accounting requirements, and the improvements in the relationship that should develop.

The university research budget is currently $4.7 billion. Using an average indirect rate of 43.6 percent, the direct labor component of the $4.7 billion is $3.273 billion ($4.7 billion divided by 1.436). Anticipated savings at this level would be $98.2 million ($3.273 billion x 0.03) or 2.1 percent of the $4.7 billion research grant award. It should be noted that the actual savings to be realized would be set by the university - Government negotiations. Also these savings may or may not result in reductions in the R&D budget since these "administrative savings" could be deployed to increase direct research funds allocated to university research.

R&D 5-2: If the new funding mechanism described in R&D 5-2 were introduced and the suggested changes in reporting requirements made, agencies could save at least $19 million the first year. This figure was derived from estimates the Task Force obtained from Federal agencies and from seven public and private universities that used the NSF redefined grant on an experimental basis. The institutions' estimated savings ranged from negligible to approximately 1.5 percent of the total Federal funds received by the university. Most frequent estimates were in the range of 0.5 to 1.0 percent. These savings to the university would be passed back to the Government through reductions in grant amounts. The following estimates are used to calculate the total savings:

- 1983 annual Federal support of universities = $4.7 billion.
- Less $ 0.9 billion already under the NSF model (at NSF) = $3.8 billion.
- $3.8 billion x 0.5% = $19.0 (low estimate)
- $3.8 billion x 1.0% = $38.0 million (high estimate).

We have conservatively estimated that savings will be at the lower end of this range. These savings result from reduction of administrative overhead and do not overlap with the savings from R&D 5-1.

Another important benefit is greater efficiency in the performance of research. University researchers and grant administrators enthusiastically support the changes included in the recommendation, and the university-Government relationship is bound to improve.

R&D 5-3: A simplified reporting system would reduce Federal and university administrative costs and strengthen Federal oversight.

No savings are quantified for this recommendation.

Summary: The chart below summarizes the net savings for this issue, assuming 10 percent annual inflation.

Summary of Savings
($ millions)

Recommedations	Year 1	Year 2	Year 3	Total
R&D 5-1	$ 98.2	$108.0	$118.8	$325.0
R&D 5-2	19.0	20.9	23.0	62.9
R&D 5-3	NQ	NQ	NQ	NQ
Total	$117.2	$128.9	$141.8	$387.9

(NQ = Not Quantified)

Implementation

All recommendations can be implemented under existing agency authority.

II. ISSUE AND RECOMMENDATION SUMMARIES (CONT'D)

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 6: RESEARCH PROGRAM REPORTING

Issue and Savings

Can unnecessary research project redundancy be reduced by use of an automated central data file as part of the research and development (R&D) project initiation and ongoing management?

The Task Force conservatively estimates that implementation of a centralized data base containing records of all non-classified, Federally funded, completed and ongoing R&D projects will reduce unnecessary program redundancy in basic and applied research by a minimum of 0.5 percent in the second year and by 1.0 percent by the third year. This will result in net savings of $71 million in the second year and $158.5 million in the third year. After accounting for the $4.0 million in start-up costs, the three-year total net savings would be $225.4 million.

Background

The need for a central depository to control and disseminate information on completed and ongoing Federally funded R&D has been considered for nearly four decades. It is estimated that in FY 1983 the Federal Government will spend $43.0 billion on R&D projects conducted by the Federal Government, industrial firms, universities and colleges, and other nonprofit institutions (excluding $1.3 billion expenditures on R&D facilities).

In addition, numerous areas of R&D involve more than one agency or multiple subdivisions of a single agency. Table II-3, on the following page, shows levels of cross-agency and cross-subdivision activity in various categories of research in the physical and environmental sciences. For example, there are 22 independent agencies and Executive agency subdivisions involved in chemistry-related research at a funding level of $532.8 million for FY 1983.

[Table II-3 on following page]

Table II-3

FEDERAL OBLIGATIONS FOR RESEARCH IN PHYSICAL AND ENVIRONMENTAL SCIENCES, BY AGENCY AND DETAILED FIELD OF SCIENCE: FISCAL YEAR 1983 (ESTIMATED)

(THOUSANDS OF DOLLARS)

AGENCY AND SUBDIVISION	PHYSICAL SCIENCES					ENVIRONMENTAL SCIENCES				
	TOTAL	ASTRONOMY	CHEMISTRY	PHYSICS	PHYSICAL SCIENCES NEC	TOTAL	ATMOSPHERIC	GEOLOGICAL	OCEANOGRAPHY	ENVIRONMENTAL SCIENCES NEC
TOTAL, ALL AGENCIES	2,846,294	386,078	532,818	1,762,371	165,027	1,097,700	390,248	369,813	252,752	84,88
DEPARTMENTS										
DEPARTMENT OF AGRICULTURE, TOTAL	68,023	-	64,250	3,773	-	13,218	5,156	8,066	-	-
AGRICULTURAL RESEARCH SERVICE	53,409	-	50,770	2,639	-	3,007	2,192	815	-	-
COOPERATIVE STATE RESEARCH SERVICE	10,021	-	10,021	-	-	1,295	1,295	-	-	-
FOREST SERVICE	4,593	-	3,459	1,134	-	8,916	1,669	7,251	-	-
DEPARTMENT OF COMMERCE, TOTAL	1,117,386	948	115,699	993,766	6,973	133,478	60,762	38,429	29,215	5,07
ENERGY RESEARCH AND TECHNOLOGY ADMIN 1/	1,071,462	390	102,678	961,421	6,973	72,095	22,983	36,011	8,029	5,07
NATIONAL BUREAU OF STANDARDS	39,647	558	12,141	26,948	-	377	-	377	-	-
NAT'L OCEANIC & ATMOSPHERIC ADMIN	6,277	-	880	5,397	-	61,006	37,779	2,041	21,186	-
DEPARTMENT OF DEFENSE, TOTAL	887,695	16,946	128,030	593,477	149,262	230,291	91,769	41,922	77,993	18,60
DEPARTMENT OF THE ARMY	179,310	-	58,451	92,126	28,733	23,529	13,134	8,734	437	1,22
DEPARTMENT OF THE NAVY	251,237	11,029	35,363	186,750	18,095	90,810	11,670	6,151	61,016	11,97
DEPARTMENT OF THE AIR FORCE	137,845	5,917	33,916	95,140	2,872	51,405	43,076	8,329	-	-
DEFENSE AGENCIES	319,303	-	300	219,461	99,562	64,547	23,889	18,708	16,540	5,41
DEPT OF HLTH & HUMAN SERVICES, TOTAL	85,615	-	76,821	8,794	-	-	-	-	-	-
ALCOHOL, DRUG ABUSE & MENTAL HLTH ADMIN	2,648	-	2,648	-	-	-	-	-	-	-
NATIONAL INSTITUTES OF HEALTH	82,967	-	74,173	8,794	-	-	-	-	-	-
DEPARTMENT OF THE INTERIOR, TOTAL	13,673	-	10,070	1,740	1,863	147,262	6,471	126,083	12,178	2,53
BUREAU OF LAND MANAGEMENT	-	-	-	-	-	250	-	-	-	25
BUREAU OF MINES	6,600	-	4,800	-	1,800	4,900	-	3,600	-	1,30
BUREAU OF RECLAMATION	-	-	-	-	-	4,473	4,323	-	150	-
GEOLOGICAL SURVEY	6,940	-	5,200	1,740	-	134,242	-	122,214	12,028	-
NATIONAL PARK SERVICE	63	-	-	-	63	3,022	2,148	69	-	80
OFFICE OF THE SECRETARY	-	-	-	-	-	175	-	-	-	17
OFF OF SURFACE MINING RECLAMATION & ENFORCEMENT	70	-	70	-	-	200	-	200	-	-
DEPARTMENT OF JUSTICE, TOTAL	200	-	-	-	200	-	-	-	-	-
DRUG ENFORCEMENT ADMINISTRATION	200	-	-	-	200	-	-	-	-	-
DEPARTMENT OF STATE, TOTAL	-	-	-	-	-	140	-	-	-	14
DEPARTMENTAL FUNDS	-	-	-	-	-	140	-	-	-	14
DEPARTMENT OF TRANSPORTATION, TOTAL	96	-	96	-	-	135	78	57	-	-
FEDERAL HIGHWAY ADMINISTRATION	96	-	96	-	-	135	78	57	-	-
DEPARTMENT OF THE TREASURY, TOTAL	1,781	-	392	249	1,140	-	-	-	-	-
BUREAU OF ENGRAVING AND PRINTING	1,781	-	392	249	1,140	-	-	-	-	-
OTHER AGENCIES										
ENVIRONMENTAL PROTECTION AGENCY	36,884	-	36,884	-	-	3,521	873	2,273	375	-
FEDERAL EMERGENCY MANAGEMENT AGENCY	4,609	-	90	4,519	-	181	181	-	-	-
INTERNAT'L DEV COOPERATION AGENCY	-	-	-	-	-	160	-	-	-	16
AGENCY FOR INTERNAT'L DEVELOPMENT	-	-	-	-	-	160	-	-	-	16
NATIONAL AERONAUTICS & SPACE ADMIN	413,407	291,980	5,900	110,402	5,125	279,172	124,212	73,934	24,028	56,99
NATIONAL SCIENCE FOUNDATION	284,574	67,551	90,888	125,651	484	286,422	100,666	76,332	108,044	1,38
SMITHSONIAN INSTITUTION	8,653	8,653	-	-	-	3,595	104	2,592	899	-
TENNESSEE VALLEY AUTHORITY	3,700	-	3,700	-	-	-	-	-	-	-
US ARMS CONTROL & DISARMAMENT AGENCY	-	-	-	-	-	165	20	125	20	-

1/ THE 1983 BUDGET PROPOSED THAT THE DEPARTMENT OF ENERGY BE REPLACED BY THE ENERGY RESEARCH AND TECHNOLOGY ADMINISTRATION WITHIN THE DEPARTMENT OF COMMERCE.

SOURCE: NATIONAL SCIENCE FOUNDATION

Given the size of the Federal R&D budget, the dispersion of R&D projects among a variety of investigators, and the degree to which multiple agencies fund or perform R&D in similar areas, there is substantial potential for redundant and costly program funding and inefficient technology transfer without a centralized information management and control system.[1] There have been efforts to provide a central data bank of completed and ongoing R&D projects in recent years.

Smithsonian Science Information Exchange (SSIE) -- SSIE evolved from the Medical Sciences Information Exchange established in 1949. SSIE collected data concerning research planned or in progress from research support agencies and individual investigators. Research information submitted to SSIE was registered on a single page, Notice of Research Project, which included:

- the name of the granting agency,
- names and addresses of principal and associate investigators,
- location of work,
- title,
- a 200-word summary of technical detail, and
- the level of effort.

The information was then coded and indexed to visible (i.e., microfiche) and electronic data processing files. Access to R&D project information was restricted to research investigators associated with recognized research institutions and research directors and administrators of cooperating Government agencies.[2]

By FY 1981, its last full year of operation, Federal appropriations for SSIE were over $2 million. The Office of Management and Budget (OMB) had proposed to transfer the service to the Department of Commerce (DOC) in that year. However, Congress withheld approval of the transfer.

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[1] Clearly, there are many situations where redundancy in R&D is both required and desirable. Frequently, a sponsor will want to initiate similar studies so that more than one group is addressing a significant problem. In other instances, sponsors will want work repeated for verification, training, or sensitivity studies. This issue, however, concerns project redundancy beyond that which is desired and necessary.

[2] Smithsonian Science Information Exchange Annual Report, 1981.

During FY 1982 budget proceedings, it was decided not to transfer the SSIE service to DOC; rather, it was recommended that funding for SSIE be cut back for each subsequent fiscal year, and that the organization become fully self-sustaining by FY 1985. The SSIE Advisory Council determined that the service could not become a viable self-sustaining entity without a sufficient lead-time at full Federal funding in order to develop a solid revenue base through marketing and product improve- ment programs. Therefore, SSIE opted to close operations in FY 1982. By the time SSIE phased out, its data base contained 300,000 citations, including non-Federal and foreign R&D, and was being updated at a rate of 100,000 new and ongoing R&D projects per year. Services provided or contemplated by SSIE prior to its demise included the following:

- administrative indexes consisting of alphabetical entries of all R&D citations by performing and supporting organization, investigators' names, and geographical location of performing organizations;
- hierarchical subject indexes of ongoing research;
- research information packages geared to specific types of research or clientele; and
- data base access both through on-line commercial vendors and directly through SSIE.

National Technical Information Service (NTIS) -- NTIS is a self-sustaining organization, under the auspices of DOC, with sales revenues of over $19 million in FY 1982. The organization was established in 1970, at which time the Clearinghouse for Federal Scientific and Technical Information was abolished and its functions transferred to NTIS.

The NTIS Bibliographic Data Base now serves as the central source for the collection and dissemination of non-classified Government-sponsored R&D and engineering reports submitted on a voluntary basis. The data base currently contains about 800,000 citations dating back to 1964 and is updated biweekly at a rate of about 65,000 new citations per year. Users access the NTIS data base through commercial on-line retrieval services or directly from NTIS.

The NTIS data base currently does not contain information on new and in-progress Federal R&D projects. It had been proposed that by FY 1981 NTIS would begin to absorb fully the functions and capabilities of the SSIE data base. A feasibility study had estimated the cost of the merger, including the expansion of the NTIS data base to accommodate SSIE's project files and conversion of the files, to be about $2.0 million. These systems were merged in FY 1983.

In 1983, NTIS developed plans with the Office of Science and Technology Policy (OSTP) to provide NTIS users with a central source of information on current Federal R&D projects. Under the arrangement, OSTP will coordinate the collection of current R&D project information. The information will then be compiled by NTIS and offered as an on-line commercial information service to the agencies affiliated with NTIS.

Methodology

The Task Force interviewed key staff personnel from OMB, NTIS, Department of Defense (DOD), National Aeronautics and Space Administration, National Institutes of Health (NIH), U.S. Department of Agriculture, General Accounting Office (GAO), and other Federal agencies, as well as private sector staff with experience in both research control and information systems. In addition, literature sources related to Government R&D were reviewed.

Findings

Interviews and studies of several large Federal research divisions showed a significant number of research projects that appear to be duplicative of other projects. The Task Force did not study the potential redundancy of individual projects. However, these cases were identified during interviews and site visits. For example, the different military Services have undertaken to develop protective clothing and gear independently of one another. Each conducts separate studies of materials acceptability, reaction, etc. In another example, several agencies are conducting parallel research on genetic engineering without cross-consultation. In a third example, at least three agencies are studying myotoxins without joint discussions of needs, funding and future plans. Finally, a 1982 GAO report discussed the funding of 11 Federal agencies to conduct research in the National Marine Pollution Program and the need for better coordination among the several agencies involved in that area of research (see Table II-4 on the following page).

[Table II-4 on the following page]

Table II-4

National Marine Pollution Program Funding by Agency and Categories in FY 1981

($ thousands)

Federal agencies	Marine Waste Disposal	Marine Mining	Marine Energy	Marine Transpor-tation	Accidental Discharges	Coastal Land Use	Information Collection and Interpretation	Cumulative Effects	Total
Department of Agriculture						$ 196			$ 196
Department of Commerce	$ 5,915	$ 602	$ 60	$ 162	$ 1,561	6,487	$3,112	$7,833	25,700
Department of Defense	5,704	306		3,900		126	2,018	257	12,391
Department of Energy	6,700		4,100		100	5,523	151	6,162	22,736
Department of Health and Human Services	715					687		3,154	4,556
Department of the Interior		40,618			520	5,392	2,160	2,500	51,190
Department of Transportation				339	3,051				3,390
Environmental Protection Agency	6,370	3,816			3,405	6,400	3,009	8,600	31,700
National Aeronautics and Space Administration							500		500
National Science Foundation								18,765	18,765
Nuclear Regulatory Commission						630	100	300	1,000
Total	$25,412	$45,422	$4,160	$4,401	$8,645	$25,919	$11,050	$47,575	$172,172

1/Funding Estimates as of June 1, 1981.

Source: GAO, Need to Strengthen Coordination of Ocean Pollution Research, July 14, 1982.

In an interview with a vice president of a highly respected private sector research firm, he reported that in his laboratories roughly 10 percent of the projects under way at any one time could be unnecessarily redundant in the absence of positive management action. In his view, many researchers have a concurrent need to achieve the same objective. Several will start similar studies to gain the desired information. At least once each year in that firm, the director actively searches out project redundancy and institutes a review to uncover unwarranted duplication. The firm then acts to consolidate its research efforts and eliminate redundancy.

Numerous interviews at key R&D agencies within the Federal Government revealed that research managers are concerned that there is no central source of information from which knowledge gained during previously conducted, Federally funded programs is available. As a result, new projects are often started in various agencies without the benefit of experience gained in similar studies conducted elsewhere.

It is currently not possible for an agency to recover information formally and comprehensively from programs of other agencies until publications are made. Some agencies, such as DOD, do not make R&D project information publicly available for reasons of national security. In others, publication usually takes a year or more.

Some agencies, such as DOD's Defense Technical Information Center and the Environmental Protection Agency's (EPA) Office of Toxic Integration, maintain their own R&D project information data bases. However, these are only agency-specific systems without interface to other agency and NTIS data bases.

Currently, there is no central data base capable of providing ready access to all unclassified, new, ongoing, and completed Federally funded R&D. The NTIS data base currently does not contain records of ongoing Federally funded R&D and only limited records of such projects are expected to be available through commercial vendors in the foreseeable future. In addition, the NTIS data base of completed R&D projects is not comprehensive. A GAO survey of Federal agencies revealed that only 64 percent of the respondent agencies submitted completed R&D project reports to the NTIS data base.3/

3/ GAO, Federal R&D Laboratories -- Director's Perspectives on Management, November 28, 1979.

A review of NTIS user statistics shows that the data base is not extensively used by Federal agencies. Only 10 percent of NTIS customers are Federal agencies, whereas 46 percent are from business and industry; 18 percent are individuals; 13 percent, universities; 11 percent, state and local governments; and 2 percent, other.

Conclusions

The Task Force has reached two conclusions. First, a comprehensive R&D information system needs to be implemented in the Federal Government; secondly, new projects should be initiated only after the sponsor states that a search has been made and that the work is not redundant. This is already a requirement in some Federal R&D divisions such as EPA's Office of Toxic Integration. The information system shoul be designed such that it may be accessed by any member of the R&D community and is readily accessible by all R&D professionals in the Federal Government.

Research personnel should be able to access easily the data base to retrieve all previous studies on a topic of interest and also to identify significant discoveries in areas of research. As an addendum, the data base should allow for cross-checking in order to eliminate redundancies.

Both the mechanism and the expertise exist within the Federal sector to establish such a system. Not only do individual agencies such as NIH, DOD and EPA have prototypes that have been tested, but the format of the NTIS system provides access key words, access terms and a method for report dissemination.

Recommendations

R&D 6-1: The NTIS data base should be expanded within limits permitted by national security needs. This expansion should include a comprehensive listing with abstracts of all current Government R&D programs, both in-house and contracted, as well as comprehensive information for completed R&D programs.

R&D 6-2: Contribution to and use of the data base by Federal agencies should be made mandatory. Further, it should be the responsibility of every sponsor to provide periodic entries into the data base as interim and final reports become available.

R&D 6-3: Every contract award and grant the Federal Government makes to fund extramural research should include a requirement that contractors and grantees supply material for the data base in the appropriate format. Contractors and grantees should be considered delinquent, and contracts and grants should be considered incomplete, unless such documents are submitted.

R&D 6-4: Every sponsor of any study, both those conducted within the Federal Government and those conducted in extramural facilities, should state in the document requesting or authorizing the study that (a) a study has been made of the literature or appropriate data bases, (b) the work for which funding is being requested or authorized has not been or is not being carried out, and (c) the study takes into account other work completed and reported.

Savings and Impact Analysis

Annual savings from instituting and implementing a comprehensive R&D data base, as recommended above, will be achieved by a reduction in the funding of undesired or unnecessarily redundant Federal R&D projects. Task Force interviews with key staff and review of representative R&D divisions in both the Federal Government and the private sector revealed that such project redundancy may range from 5 to 10 percent of program funding for basic and applied research. However, in calculating the savings to be realized Government-wide by implementation of its recommendations, the Task Force considered these factors:

- There is redundancy in the Federal R&D budget that is, indeed, warranted.
- A significant portion of the R&D budget consists of programs of a classified nature which would not be included in the proposed central data base (a reliable estimate of the dollar amount, however, is not available).
- There is ongoing research that, even if found unnecessarily redundant, could not be immediately curtailed.
- The process of uncovering areas of redundancy and pinpointing specific projects as unwarranted will require time and careful consideration.

Consequently, the Task Force's calculation of potential savings in this issue conservatively assumes that the level of unwarranted redundant R&D that can be eliminated in the second year of implementation represents 0.5 percent of the total estimated Federal basic and applied research for FY 1983 ($13.3 billion). This percentage is assumed to increase to 1.0 percent by the third year. The Task Force analysis assumes no savings will be realized and that a start-up cost will be incurred in the first year of implementation of its recommendations. These costs would primarily involve the development of a standardized reporting format and method for all agencies and contractors involved in Federally funded R&D at an estimated first-year cost of $4.0 million. Subsequent annual operating costs are estimated to be $2.0 million. Savings are calculated as follows (figures are inflated 10 percent per year):

Savings Calculations

	($ millions)			
	Year 1	Year 2	Year 3	Total
Savings from Year 1 project reductions (0 x $13.3 billion)	--	--	--	--
Savings from Year 2 project reductions (.005 x $13.3 billion)	--	$ 73.2	--	$ 73.2
Savings form Year 3 project reductions (.01 x $13.3 billion)			$160.9	$160.9
Cumulative gross savings	$ -0-	$ 73.2	$160.9	$234.1
Implementation and operating costs	$ (4.0)	$ (2.2)	$ (2.4)	$ (8.6)
Cumulative net savings	$ (4.0)	$ 71.0	$158.5	$225.5

Implementation

Implementation of the Task Force's recommendations can be done by the agencies involved.

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 7: NASA COST REPORTING

Issue and Savings

Can project management in the National Aeronautics and Space Administration (NASA) be strengthened by expanding the scope and coverage of the systems used to manage NASA resources to include Civil Service personnel?

The Task Force believes that the recommendation presented in this issue will permit NASA to improve the overall management of the agency. No specific savings are attributed to this management improvement.

Background

NASA's budget is divided into three major appropriation accounts:

- Research and Development (R&D) -- funds the study, development and acquisition of space systems to carry out the NASA mission. Of all the funds appropriated in this account, 93 percent are used to contract out the study and development activities.
- Construction of Facilities -- covers the facility planning and construction activities to support NASA operations.
- Research and Program Management (R&PM) -- funds all internal NASA activities including the planning of new space projects; the management of the space projects currently being developed; actual design and development activities on existing space projects; support and management of operational space missions; and the work done in the support and management of the research and development contracts.

Since its inception, NASA has reported its project costs as incremental costs to the agency for conducting a project, i.e., any costs incurred specifically to support a project. All other costs including Civil Service employees and launch, tracking and data acquisition costs within existing capabilities are not considered incremental to any project and therefore are not included in project costs. This type of reporting distorts the true cost picture of any project.

Methodology

In developing this issue, the Task Force conducted interviews at NASA, the Office of Management and Budget (OMB) and the General Accounting Office (GAO) to further define the problem and to attempt to understand fully the background of the issue. These interviews were supplemented by a review of several GAO reports.

Findings

NASA has a well-defined automated system for managing the space projects it undertakes. The primary focus of management is on the contractors responsible for developing the various NASA projects. The extent of NASA internal manpower resources employed on a project and how they are utilized are not specifically included in the management process.

As part of overall project planning, NASA does require an estimate of the internal manpower resources required to complete a project. However, internal project management during the life of a project does not report on the actual utilization of the people, and subsequent planning does not cover these resources except in emergency situations.

These internal resources can be significant on a total project basis. The following table, derived from two separate GAO reports on the subject 1/, shows that the unreported project costs attributable to Civil Service personnel ranged from 13 percent to 34 percent of total project cost. This means that NASA reports on the cost of these projects significantly understate real costs.

Project	GAO Estimate of Costs of Civil Service Personnel as a Percent of Project Costs *
Atmosphere Explorers - C, D, and E	34%
Orbiting Solar Observatory - I	20%
Nimbus G	13%
Space Telescope	20%

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* Project costs are used as the base since that is the basic number reported by NASA.

These data apply to total projects. The percentages could be much higher as a percent of project cost on individual components or subsystems. In certain situations the entire subsystem, or a major part, may be developed in-house.

According to the GAO studies, the problem goes beyond the basic development cost. In the case of the Space Telescope, GAO found that NASA was significantly understating the full life cycle costs as well.

	Development Cost	Operation Cost ($ millions)	Life Cycle Cost
NASA estimate	$ 530	$ 600	$1,130
GAO estimate (included Civil Service costs and inflation)	$ 716	$1,473	$2,189

1/ GAO, *Need For Improved Reporting and Cost Estimating On Major Unmanned Satellite Projects*, PSAD-75-90, July 25, 1975.

GAO, *NASA Should Provide the Congress Complete Costs Information on the Space Telescope Program*, PSAD-80-15, January 3, 1980.

Another GAO study 2/ criticized NASA for not including "relatively fixed" costs for "Civil Service support; general support costs for launch vehicles, tracking and data acquisitions; or costs incurred by other agencies supporting the projects." Specific examples cited by GAO include:

	Unreported Costs
Space Shuttle	$ 2.3 billion
HEAO A-C	$77.8 million
Mariner Jupiter/Saturn 1977	$47.9 million
Pioneer Venus	$19.6 million

These examples clearly indicate significant costs associated with space projects that are not being covered in the management of the individual projects.

Another estimate of the magnitude of this problem can be developed from the FY 1983 budget. The budget for the total R&PM account is $1.229 billion. If the $176 million budgeted for other services is removed, $1.05 billion would represent the total internal NASA budget for 22,382 full-time equivalent (FTE) employees. The NASA Comptroller's Office estimates that 30 to 50 percent of NASA personnel are currently employed on the various projects.3/ Accordingly, $315 to $525 million of project work is not actively being covered in the project management system.

GAO has repeatedly criticized NASA for not including these costs in the reports submitted to Congress. NASA response to GAO always addresses the following points:

o The NASA Civil Service staff is a vital national resource necessary to provide a capability but is insensitive to the changes in project requirements. As such, if a project is added or deleted the Civil Service costs will not change.

2/ GAO, Improved Reporting Needed on National Aeronautics and Space Administration Projects, PSAD 77-54, January 27, 1977, p.8.

3/ The remainder of the Civil Service personnel are involved in overall agency management, advanced development and preliminary project planning such as the Space Station.

- There is a need to maintain flexibility in the utilization of the Civil Service staff. When individual projects enter difficult periods, NASA wants the ability to assign staff to the contractor's facility to assist in problem resolutions or to bring a certain aspect of the project inhouse for better control.
- The economic costs of a project to the NASA budget should not include the Civil Service costs since these costs would not be avoided if a project were canceled.

Conclusion

Based on our experience in the private sector, the Task Force believes that NASA must expand its project management systems to include the internal resources that are available to it. The 22,000 person-years of effort per year should be controlled to the same degree as the R&D monies in pursuit of NASA's mission. This does not necessarily imply that the total resource level would change as a result of individual project decisions. It does mean that decisions should be made on the basis of current and planned project work load.

Recommendation

R&D 7: NASA should expand its project management systems to cover all resources available to it. The $1.2 billion made available to NASA in the research and program management account is just as important from a management perspective as the $5.3 billion in the R&D account.

Savings and Impact Analysis

No specific savings are estimated for this issue since it is primarily a management improvement issue. Certainly, economies are possible if NASA would plan, monitor and control its internal resources to the same degree it does its money for contractual services.

Implementation

The recommendation contained in this issue can be implemented by the NASA Administration. It is not a new recommendation, having been made by both OMB and GAO for over ten years. From the private sector perspective, we do not accept NASA's rationale for not implementing it, since implementation can only lead to improved management.

II. ISSUE AND RECOMMENDATION SUMMARIES (CONT'D)

RESEARCH AND DEVELOPMENT (CONT'D)

R&D 8: COMPENDIUM OF SELECTED R&D ISSUES

Issue and Savings

What are the research and development (R&D) opportunities for cost savings or revenue generations identified by other President's Private Sector Survey (PPSS) Task Forces not discussed in detail in this Report?

Additional three-year savings/revenue generation of $32,984.2 million are projected from implementation of the 97 PPSS recommendations. These are primarily the result of improvements in strategic planning and R&D management and the budget process.

Background

This compendium consists of R&D issues not reported elsewhere in this Report. We have decided to include these savings as a compendium issue to portray the total benefit of R&D improvements identified by PPSS Task Forces. Including these savings as a compendium issue allows their inclusion without repetitious descriptions of similar kinds of improvements in a number of agencies.

The savings reported in the Issue and Recommendation Summaries are duplicated in other reports, but will be netted out in the President's report to avoid double counting. These recommended savings and revenue opportunities are presented here to demonstrate the importance of the Federal Government's need to focus on these opportunities.

Findings

In addition to the seven specific issues discussed previously, numerous other R&D issues were identified by PPSS task forces.

A review of these issues confirms that the R&D improvements most needed in Government are in the key areas of strategic planning and R&D management and budget cycle.

Conclusion

There are many agencies and applications that would benefit greatly from R&D management improvements. The number of these issues and savings/revenues represented support the Task Force's position that greater attention and improvement is needed Government-wide for R&D management.

Recommendation

R&D 8: The President, Congress, and specific agencies should take steps recommended by other PPSS Task Forces to improve R&D management.

Savings and Impact Analysis

Savings/revenues included in this compendium issue are listed in Exhibit II-15 on the following page.

Implementation

Implementation requirements can be found in the issues in each Task Force report.

[Exhibit II-15 on the following page]

Exhibit II-15

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
AG 49	Improve research activities.	3	$ 6.0	$ 8.2	$ 10.8	$ 25.0	S
AG 51	Establish National Research Board and realign regions.	2	76.0	83.6	91.9	251.5	S
AG 53	Transfer selected human nutrition research programs to HHS.	1	15.0	38.0	42.0	95.0	S
AG 54	Eliminate 8 percent contribution to funding of 20 low-priority research programs that can be funded by other than Federal sources.	1	10.7	11.8	12.9	35.4	S
USAF 3	Planning, programming and budgeting: Consolidate program and budget reviews thereby eliminating duplication of efforts.	3	2.4	2.6	2.9	7.9	S
USAF 19	Multiyear procurement (MYP): Expand use of MYP for weapons systems acquisition and revise budget priorities to accommodate more MYP.	2	800.0	800.0	800.0	2,400.0	S
ARMY 11	Procurement stability: Institute a biennial budget system for procurement of major weapons systems, with constraints designed to ensure that programs are managed in an informed, documentable way.	5	2,000.0	2,200.0	2,420.0	6,620.0	S

Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
BUS-FTC 1	Restrict the scope of economic research to projects directly related to FTC mission.	9	$ 1.5	$ 1.6	$ 1.8	$ 4.9	S
BUS-TVA 7	Reduce appropriations for National Fertilizer Development Center Program; seek alternative sources of revenue such as user fees, special sales taxes on fertilizer, etc.; also reduce staff level and make administrative changes.	4	12.1	27.1	44.6	83.8	S
COMM 8	Enhance the process for reviewing National Bureau of Standards projects.	3	10.0	15.0	20.0	45.0	S
OSD 18	Independent R&D costs: These costs should be recoverable by defense contractors in the same manner as other bona fide overhead expenses. The burdensome regulatory process currently used should be eliminated, thus significantly reducing manpower and administrative costs.	1	100.0	110.0	121.0	331.0	S
OSD 19	R&D Laboratories: Improve the exchange between the services and the defense research laboratories so that information on emerging technology developments can be better integrated into the appropriate phases of the weapons acquisition process. Coordination is also needed to eliminate duplication of staff and research efforts.	1	233.1	513.6	847.0	1,593.7	S

348

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Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
OSD 21	Weapon systems new starts: Install self-disciplinary limits on the number of new weapons programs started each year. Before a new start is approved, an estimate should be made of the projected cost of that new weapons system through production. Then, DOD should consider the impact of that incremental cost on the overall acquisition process -- in view of the limited funds for all weapons systems. Limits on new starts would help to ensure that sufficient funds are available to carry out all weapon programs economically and efficiently.	1	$ 222.9	$ 490.4	$ 809.2	$1,522.5	S
OSD 23	Instability in the weapons acquisition process: Commit to a stable five-year spending plan for the acquisition of weapons systems at economical production rates. DOD should focus the attention of Congress on any significant increase in costs that would result from proposals to change the plan. Critical to achieving such a plan for program stability is DOD's ability to relate financial affordability to proposed new systems early in the budgetary cycle. This would avoid accumulating systems that cannot be funded in economic production quantities during the entire production cycle.	2	1,051.5	2,313.3	3,816.9	7,181.7	S

Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
ENERGY 11	Establish mission for multi-program national laboratories.	2	$ 0	$ 0	$ 0	$ 0	
ENERGY 12	Eliminate DOE overmanagement of contract R&D.	1	0	0	0	0	
ENERGY 13	DOE proposed three-year rolling R&D budget procedure.	1	125.0	137.5	151.2	413.7	S
ENERGY 14	Develop more DOE-industry interaction in R&D.	1	0	0	0	0	
ENERGY 15	Give priority to funding special nuclear materials and proceed with new production reactor.	3	0	0	0	0	
ENERGY 16	Support expeditious completion of defense waste processing facility.	2	0	0	0	0	
ENERGY 17	Terminate one of three current approaches to internal confinement fusion.	2	30.0	49.5	54.4	133.9	S
ENERGY 18	Utilize defense industrial security program versus more expensive current procedures.	2	15.0	16.5	18.1	49.6	S
EPA 6	Close six regional EPA laboratories.	1	(0.2)	10.3	11.4	21.5	S
EPA 7	Centralize research data base; cease funding for Centers of Excellence; conduct more cooperative research agreements in-house.	5	4.8	5.5	6.0	16.3	S

Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
EPA 8	Close ADA research laboratory and Isle Field Station.	2	$ 2.2	$ 2.2	$ 2.5	$ 6.9	S
HHS 4	Eliminate the policy research of HHS department management.	2	13.9	15.3	16.8	46.0	S
HHS 5	Eliminate evaluation of projects within the Office of the Secretary.	2	10.5	11.6	12.7	34.8	S
HHS 7	Modify management practices and the organizational structure of HHS to improve social research.	4	20.0	22.0	24.2	66.2	S
PHS 1	Reduce administrative cost of NIH grants, contracts and equipment to universities which receive grants.	3	167.5	184.2	202.7	554.4	S
PHS 5	Consolidate Federal toxicology testing programs.	2	40.5	70.8	49.4	160.7	S
PHS 6	Eliminate inconsistencies in the NIH grants process.	2	5.2	5.7	6.3	17.2	S
PHS 8	Close the Rocky Mountain Laboratory of NIH.	2	2.9	5.3	5.9	14.1	S
NAVY 1	Limit number of programs put into production; fund management reserve to deal with fiscal emergencies and reduce stretch-outs; stabilize PPBS process; establish two-year budget cycle.	4	1,000.0	1,000.0	1,000.0	3,000.0	S

371

Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
PRIV 3	Expand National Transportation System legislation to allow the private sector to invest in the fifth and future space shuttles and expendable launch vehicle systems; initiate Government/industry cooperation agreements to provide incentives for private investments.	2	$ 460.0	$ 506.0	$ 556.6	$ 1,522.6	S
PROC 4	Expand use of multiyear contracting in all Federal agencies; simplify budget process and utilize discounted cash flow methodology to evaluate the relative attractiveness of multiyear candidates.	5	500.0	1,100.0	1,815.0	3,415.0	S
PROC 6	Develop comprehensive Program Management and Acquisition Plan with expanded scope; use plan as basis for cost and schedule estimates; decentralize program management in accordance with approved plans.	1	300.0	825.0	1,815.0	2,940.0	S
DOT 1	Establish a new organization structure to encourage an overall R&D management approach; promote joint efforts in transportation R&D.	3	85.5	94.6	104.1	284.2	S

Exhibit II-15 (Cont'd)

R&D ISSUES COVERED IN OTHER REPORTS

Issue	Subject	Number of Recommendations	Savings/Revenues ($ millions) Year 1	Year 2	Year 3	Total	Savings(S)/ Revenue(R)
DOT 10	Consolidate Federal Railroad Administration R&D and safety functions; impose user fee schedules for system assessments and R&D services to railroads.	5	$ 5.0	$ 5.1	$ 5.2	$ 15.3	S
			13.2	21.7	31.5	66.4	R
	Total Savings (S)		$7,329.0	$10,690.3	$14,898.5	$32,917.8	S
	Total Revenue (R)		13.2	21.7	31.5	66.4	R
	Grand Total Savings and Revenue		$7,342.2	$10,712.0	$14,930.0	$32,984.2	

373

III. SUMMARY LIST OF RECOMMENDATIONS AND SAVINGS

This section summarizes the annual and cumulative savings for each issue in the report.

The authority required to implement the individual recommendations is also shown according to the following legend:

A -- recommendations can be implemented under the existing authority of the agency.

P -- recommendations can be implemented under the existing authority of the President.

C -- recommendations can be implemented by action of the Congress.

III. SUMMARY LIST OF RECOMMENDATIONS AND SAVINGS

THREE-YEAR COST SAVINGS (S)/REVENUE (R)/CASH ACCELERATION (CA) OPPORTUNITIES

Issue	Recommendations	Implementation Authority 2/	Savings (S)/Revenue (R)/Cash Accelerations (CA) 1/ ($ millions) Year One	Year Two	Year Three	Three-Year Total
R&D 1	**Strategic Planning**					
	Develop statements of goals; develop improved strategic planning concepts & procedures; and use strategic planning for subsequent operational management.	A	$2,200.0	$2,400.0	$2,700.0	$7,300.0 (S)
R&D 2	**R&D MGT and the Budget Process**					
	Implement multiyear budgeting for R&D; develop budget concept to reduce level of detail; shorten budget cycle; and reduce technical staff positions in all R&D agencies.	C	1,110.0	1,220.0	1,340.0	3,670.0 (S)
R&D 3	**Privatization**					
	Identify privatization opportunities; identify R&D activities which compete with private sector; and encourage private sector participation.	A				3/
R&D 4	**Laboratories**					
	Form additional centers of excellence; form a laboratory evaluation team; study lab consolidation; Directors of labs should have more budget control; create a scientific/technical personnel system; reclassify facilities and remove exemptions from A-76.	A,C	153.0	168.3	185.1	506.4 (S)

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III. SUMMARY LIST OF RECOMMENDATIONS AND SAVINGS

THREE-YEAR COST SAVINGS (S)/REVENUE (R)/CASH ACCELERATION (CA) OPPORTUNITIES

			Savings (S)/Revenue (R)/Cash Accelerations (CA) 1/ ($ millions)			
Issue	Recommendations	Implementation Authority 2/	Year One	Year Two	Year Three	Three-Year Total
R&D 5	Administration of Research Grants to Universities					
	Negotiate indirect cost rates that include fixed amount for departmental administration; encourage agencies to implement new funding and grant administration mechanism; and develop simplified method for determining indirect rates for universities with less than $10 million total grants.	A	$117.2	$128.9	$141.8	$387.9 (S)
R&D 6	Research Program Reporting					
	Expand NTIS; make use of NTIS data base mandatory; require that research performers supply material; require that research performers supply material; and require that research performers utilize data base before initiating new research.	A	(4.0)	71.0	158.5	225.5 (S)
R&D 7	NASA Cost Reporting					
	Expand project management system to cover all resources.	A				3/
R&D 8	Compendium Issue	A,C,P	7,329.0 13.2	10,690.3 21.7	14,096.5 31.5	32,917.8 (S) 66.4 (R)
	Total Cost Savings (S) Total Revenue (R)		$10,905.2 $ 13.2	$14,678.5 $ 21.7	$19,423.9 $ 31.5	$45,007.6 (S) $ 66.4 (R)
	Total Cost Savings and Revenue		$10,918.4	$14,700.2	$19,455.4	$45,074.0

1/ Amounts in this summary include inflation and are net of implementation cost.
2/ Implementation Authority: Agency (A), President (P), Congress (C).
3/ Recommendation not quantified.

IV. COST CONTROL OPPORTUNITIES FOR FURTHER STUDY

A. UNIFORM PATENT AND TECHNICAL DATA POLICY

Issue

Can a revised patent and technical data policy improve the transfer of Government-funded innovation to industry and enhance cooperative research projects between Government and the private sector?

Background

Patents -- The lack of a uniform patent policy resulted in the issuance of the Presidential Memorandum and Statement of Government Patent Policy in 1963. This memorandum was revised in 1971, providing further guidance to agencies for assigning title to inventions resulting from Federally funded research. These attempts toward uniformity have been relatively unsuccessful and policies have been developed over the years on an agency-by-agency basis. There are wide variances in the way agencies have interpreted the Presidential policy, vesting title to inventions in the Government in one instance and in the contractor in another. There has also been piecemeal legislation that further complicates implementation of this policy. In fact, there are 20 different patent arrangements used by the agencies.

The 96th Congress enacted P.L. 96-517, providing that in most cases a nonprofit organization or small business firm may elect to retain title to inventions made during Federally sponsored research and development (R&D). Pending bills would extend P.L. 96-517 to all Government contractors (Schmitt Bill, S. 1657 and Ertel Bill, H.R. 4564).

Technical data -- The Government needs many kinds of technical data, particularly in the Department of Defense (DOD), from the simplest gadget to the most sophisticated equipment. To maintain competition among suppliers and to further economy in Government procurement, these data are available, with certain exceptions, in the form of contract specifications.

The Government has unlimited rights to all data resulting from Government-sponsored research and development, whether it be totally financed or a joint venture with a contractor. If data are developed at the contractor's expense, then the Government is responsible for keeping it secret; its disclosure to competitors could jeopardize the competitive advantage it was developed to provide. The Government has limited rights to this data which should not be transferred to a third party under the Freedom of Information Act (FOIA). Any public disclosure of technical data can cause serious economic hardship to the originating company.

License -- The Federal Government has a portfolio of 28,000 to 30,000 patents. Less than 10 percent of them have been licensed to private producers. The Government also follows a practice of filing patent applications for inventions with little or no commercial value. Under present legislation and Defense Acquisition Regulation, the contractor can request a waiver of title to inventions, thereby vesting title to the invention in the contractor rather than the Government (when the invention results from Government-sponsored R&D).

Methodology

The following approach was taken to develop and validate the conclusions reached:

- Present agency practices were determined through literature review and interviews with agency patent and technical data personnel.
- Present and pending legislation was reviewed.
- Objectives were discussed with drafters of the new Federal acquisition regulations.
- Industries' concerns were reviewed and evaluated.
- The above information was analyzed.

Findings

The lack of a uniform patent and technical data policy results in the following:

- There are 20 different patent arrangements used by the agencies.
- Major contractors do not have access to Government-sponsored innovation.

- There is a reluctance in the private sector to make use of Government-sponsored innovation in the absence of exclusivity.

- Many contractors are reluctant to transfer their proprietary data to the Government for fear of disclosure to competitors. Also, many contractors will not accept Government contracts because they fear the disclosure of sensitive technical data. These fears confirm the need for legislation or regulations that would guarantee the contractor protection from disclosure. This type of law would improve the working relationship between Government and the private sector and further enhance competitive bidding.

- DOD waives title to 90 percent of Government-sponsored innovation back to the contractor, while the National Aeronautics and Space Administration and Department of Energy waive 85 percent and 80 percent, respectively. Most contractors only request a waiver for inventions with some commercial value. The Government usually files patent applications for the remaining inventions, resulting in a Government patent portfolio with a large percentage of patents with no commercial value. For instance, of the 7,000 patent applications filed by DOD from 1976 to 1981, about 40 percent are contractor generated and the remaining 60 percent are generated by DOD employees. Also, 90 percent of the licenses granted are for employee-generated inventions.

- At present, there is no legislation affecting the rights to technical data. There is, however, P.L. 96-517 pertaining to patent rights in small businesses and universities.

Conclusions

A uniform, clear patent and technical data policy would stimulate innovation, productivity and commercial use of Government-funded innovations. It would also reduce the administrative burden on the agencies and contractors and increase the willingness of contractors to enter into Government contracts.

Recommendations

Patent Policy Needs -- The Task Force supports the following recommendations on patent policy:

- Support the Schmitt Bill. However, should the Schmitt Bill not pass, the 1971 Presidential Statement on Patent Policy should be revised to require agencies, where not precluded by law, to give the first option to ownership of inventions made in performance of a Government contract to the inventing contractor.
- Support a policy of defensive patent or defensive publication in lieu of a regular patent. This policy would require the agency to state clearly whether it will file a defensive patent or defensive publication or a regular patent application. If the agency elects to file a regular patent application, the invention should be subjected to a coordinated screening process to determine its commercial value.
- The screening process should be coordinated with a licensing program. Government licensing should be consolidated into a single agency. The single agency should also have primary responsibility for transferring that technology to the private sector.
- Inventions should be classified in a catalog based on field of technology.

Technical Data -- For technical data matters, the Task Force recommends the following:

- Data developed completely at private expense confers on the Government limited rights to the data. The Government should not release that data to a third party under FOIA.
- Contractors should maintain rights to background data developed by the contractor at the contractor's expense prior to entering into a Government contract. The Government should have specific rights to all other data. If background information is turned over to the Government, it must be treated as limited rights data.
- Contractors should retain all commercial rights to all data first produced under Government contract. The Government would have a license for limited purposes such as reprocurement,

evaluation and similar needs. This data should not be disclosed without having a specific Government purpose or without the agreement of the contractor.

Savings and Impact Analysis

A policy of defensive patent filing or defensive publication would:

- decrease the number of useless patents in the Government portfolio;
- reduce the related cost of filing patent applications;
- reduce the burden in the patent office as required by agency filing; and
- provide the same defensive protection as a regular application.

Consolidation of Government licensing in a single agency would prevent fragmentation and inconsistency in the licensing process.

Passage of the Schmitt Bill would vest title to Government-sponsored R&D in the major contractors, thereby enhancing the relationship between Government and major contractors. It would also stimulate the commercialization of innovation (P.L. 96-517 gives small businesses and universities title to Government-sponsored innovation and has been well received by the parties involved). Also, the number of inventions reported by these contractors has increased significantly.

Contrary to FOIA, the Government should not disclose to third parties data developed solely at private expense. Confidentiality would (a) encourage inventors to share their information with the Government; (b) make more innovation available to the Government; and (c) significantly encourage competitive bidding. At present, many contractors refuse to enter into Government contracts for fear of the Government's disclosure of sensitive proprietary data.

Implementation

The above recommendations can be implemented through legislation (Schmitt Bill), through a revised Presidential statement on patent policy, and through a Presidential statement on rights in technical data.

IV. COST CONTROL OPPORTUNITIES FOR FURTHER STUDY (CONT'D)

B. MEASURING R&D OUTPUTS

Issue

Can research and development (R&D) management in the Federal Government be strengthened if increased attention is given to developing and employing quantitative measures of R&D performance?

The lack of such measures, particularly in basic and applied research areas, leads to a lack of precision in managing R&D. In particular, Government science policy formulation, project selection and program evaluation can benefit from the increased use of quantitative measures.

While it seems likely that the use of quantitative performance measures can make the R&D management process more efficient and effective, it is difficult to ascertain the nature of savings opportunities generated by their use.

Background

The history of modern management shows that one of its outstanding traits has been the attempt to rationalize decision-making in organizations. Management historians often identify the origins of modern management with the turn of the century work of Frederick W. Taylor who, with his concept of scientific management, attempted to apply scientific principles to organizing the management process. For example, he called for management to collect data on the work place, "... recording it, tabulating it, reducing it in most cases to rules, laws, and in many cases to mathematical formulae."1/

The drive to rationalize management through quantification has met with only limited success in the R&D area.

1/ F.W. Taylor, "The Principles of Scientific Management," in Boone and Bowen (eds.), The Great Writings in Management and Organizational Behavior (PPC Books, 1980), p. 43.

It has been applied more successfully to the management of technology than the management of science. Even within technology, its effective use has been spotty.

The degree of success or lack of success in applying quantitative techniques to the management of R&D seems to be rooted in two factors: the level of uncertainty in an R&D project and the availability of measures of R&D performance. In the first instance, the higher the level of certainty associated with a project, the more amenable it is to quantitative management. Thus, heavily used quantitative techniques, such as Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM) are very useful in large scale projects whose tasks can be accomplished with an established degree of certainty, but may be of very limited value to more basic research projects whose outcomes are only vaguely predictable.

With the availability of R&D performance measures, we find, not surprisingly, a positive correlation between the availability of quantitative measures of R&D performance and the extent to which they are employed for R&D management purposes. In general, the nearer a project is to the development end of the spectrum, the more measures there are that are available. Typically, there are technical performance indicators (e.g., How fast does a newly developed aircraft fly? How far can it travel without refueling? What is its rate of climb?), or business (or organizational) performance indicators (e.g., How much does the new technology contribute to organizational profitability? To cost reductions in manufacturing? To increases in labor productivity? To increases in market share?). In the sciences, the only readily available performance indicators are those associated with research publications (e.g., counts of scientific articles, citations, coauthorships).

Methodology

Interviews were conducted with key evaluation people in several agencies, as well as with some of the central individuals involved with developing quantitative indicators of scientific and technological effort. Relevant literature was reviewed.

Findings

Little effort is being made in the Federal Government to develop and refine quantitative measures of scientific and technological performance. Only two agencies seem to have made an explicit commitment to encouraging their development: the National Science Foundation (NSF) and the National Institutes of Health (NIH).

Within NSF, the Science Resource Studies Division (SRS) and the Science Indicators Unit are explicitly charged with developing and using quantitative indicators. SRS maintains and collects a wide array of science and technology (S&T) statistics. It is primarily through its efforts that we have any idea at all of the quantitative dimensions of S&T in the U.S. It serves as the principal repository of data on such things as S&T manpower, employment, expenditures, and education. In addition to maintaining and publishing R&D statistics, SRS supports extramural research designed to more fully exploit existing data and to push forward the state-of-the-art of indicators development.

The Science Indicators Unit is responsible for publishing the Science Indicators reports every two years. These reports provide the most comprehensive statistical summary that exists of U.S. scientific and technological activity. They also contain a comprehensive chapter on international indicators. In addition to publishing the reports, the Science Indicators Unit commissions studies on the strengths and weaknesses of different indicators.

NIH does not have any divisions analogous to SRS or the Science Indicators Unit. Nonetheless, it has been an important supporter of indicators development for basic and applied research. The Program Planning and Evaluation group in the Director's Office has been supporting the development of measures of scientific output for over a decade. Individual institutes, such as the National Heart, Lung, and Blood Institute (NHLBI), have also supported efforts to develop better science indicators. The reason for substantial NIH interest in developing good measures of scientific performance is a desire to be able to evaluate the outcome of billions of dollars of biomedical research supported by the agency each year.

On a much smaller scale than NIH or NSF is the Office of Technology Assessment and Forcecast (OTAF), which is trying to develop patent data for the purpose of examining both domestic and foreign technological events. OTAF has undertaken a number of studies that identify the most prevalent patenting areas in the U.S. today, as well as identify where foreign firms are making the most significant technological inroads in the U.S.

All the efforts described here are laudable. The problem is that together they are too small to lead to the development of a true system of interrelated, easily accessed, detailed R&D statistics. Without such a data network, it is unlikely that quantitative measures of scientific and technological performance can have widespread application.

Policy uses of S&T performance indicators can be substantial. It is inconceivable today that economic policy would be made without heavy dependence upon analyses of economic indicators. Rising inventory levels are one indication that the economy may be entering a recession. Increased capital spending may suggest that a sick economy is recovering. Increases in the money supply portend inflationary pressures, while decreases may contribute to rising interest rates. Examination of these indicators gives us some idea of what is happening in the economy today and may suggest future courses of action.

While it is unlikely that S&T indicators could ever assume the significance of economic indicators, it certainly seems plausible that they could play an important role in guiding science policy formulation in the U.S. Some of these indicators are in fact now used as inputs into policy formulation, but their use is generally haphazard.

There are two principal ways in which quantitative indicators of scientific and technological performance can be very useful in the making of American science policy. First, they have a purely domestic use, telling us where we have come from and possibly suggesting where we are going. Second, they can be important in alerting policymakers to foreign scientific and technological activity that can have commercial, foreign policy and military implications.

Domestic Policy Uses of Scientific and Technological Indicators -- If we had a well-developed, comprehensive body of indicators of national scientific and technological performance, we could have a good idea of national S&T capabilities, both in the recent past and at the present time. This information could serve as a guide suggesting where we are heading. If we do not like the projected future directions of S&T, we can implement policies to modify them.

For example, measures of current enrollments in, say, university biochemistry programs coupled with information on the number of biochemists presently employed in the Government, nonprofit, for-profit, and university sectors; data on published biochemical research; and present research funding levels in biochemistry can give planners a very good idea of the potential state of American biochemistry efforts five years from now.

Consider also the following concrete example: During the years following the oil embargo, the Department of Energy (DOE) and its predecessors focused a great deal of attention on alternative energy sources. One problem it faced in managing R&D in alternative energy areas was its lack of knowledge of who was already doing research in the target areas, the general dimensions of their efforts, and the specific contents of ongoing activities. DOE was able to obtain a good grasp of coal gasification R&D activity by tabulating information from existing data sources on all articles, reports, and patents related to coal gasification. It was even able to identify R&D activity occurring overseas. One product of the investigation is presented here as Exhibit IV-1, on the following page, which shows the organizations most active in undertaking coal gasification R&D efforts.

Monitoring Foreign Scientific and Technological Activity -- For a long time after World War II, roughly half of the world scientific and technological effort was undertaken in the U.S. Americans dominated world science and technology like no other country in history. However, beginning in the 1970s, it became clear that the absolute dominance of the Americans was on the wane. It was not so much that American R&D capabilities were deteriorating; rather, the rest of the world was catching up to the U.S. As a consequence, American products no longer enjoyed the advantage of being the best engineered products in the world. This contributed to a loss of market share in international markets. In more recent items, high-quality, low-cost technology based products have even made serious inroads in the United States marketplace. The automobile and consumer electronics industries have been particularly hard hit by technology-based competition from Japan.

Scientific and technological indicators can provide policymakers with valuable information on foreign S&T activity abroad, as well as inside the United States. Of particular value are patent indicators. Anyone monitoring these indicators in the mid-1960s would have found that foreign individuals and organizations accounted for only 20 percent of all U.S. patents. Today, however, they account for 41 percent. Particularly revealing is the fact that 14 percent of U.S. patents are currently held by Japanese organizations and individuals.

[Exhibit IV-1 on the following page]

Exhibit IV-I

INSTITUTIONS HAVING THE GREATEST NUMBER OF PUBLICATIONS IN COAL GASIFICATION

Private Sector	No. of Pubs
Institute of Gas Technology	68
Battelle Columbus Laboratories	25
Westinghouse Electric Corp.	24
Bituminous Coal Research	23
Exxon Research & Engrng.	20
Consolidation Coal Co.	20
General Electric Co.	14
Koppers Company	13
Parsons Company	12
Chemical Systems Inc.	12
University Sector	
City College of New York	12
Brigham Young University	10
West Virginia University	8
Carnegie-Mellon University	8
University of Michigan	8
Pennsylvania State University	7
Iowa State University	7
University of Kentucky	6
Purdue University	6
University of North Dakota	4
Government Sector	
DOE/ERDA/BM/OCR	83
Lawrence Livermore Labs	56
Pittsburgh Energy Research Center	39
Morgantown Energy Research Center	30
Oak Ridge National Laboratory	23
Sandia Laboratories	19
Laramie Energy Research Center	17
Argonne National Laboratory	15
Los Alamos Science Laboratory	7
Atomic Energy Commission	7

Exhibit IV-2, on the following page, illustrates the great level of detail that patent indicators can provide policymakers regarding foreign patenting in the U.S. It is a patent profile for the Sony Corporation and shows the areas in which this company has taken out patents in the U.S. Inasmuch as Sony does not advertise its technology strategy in the U.S., this patent profile gives policymakers unobtrusive insights into what that technological strategy might be.

Agencies can use measures of R&D outputs to evaluate the effectiveness of their programs. In 1982, the Federal Government spent some $13.3 billion to support basic and applied research. It is quite difficult to evaluate whether or not this money was well spent, since the outputs of scientific research are notoriously hard to evaluate. Ideally, the output measures would tell us that a given piece of research resulted in certain tangible benefits. However, this is rarely the situation; basic and applied research infrequently have clear-cut, measurable, useful results.

However, scientific research often results in the publication of scientific papers which describe the research findings. In recent years, counts of scientific papers have become an accepted measure of scientific output. Universities, for example, have long assessed the publication productivity of their faculties, especially when making promotion and tenure decisions -- the famed "publish or perish" approach.

While counts of published papers do not tell us anything about the usefulness of research, they do give us an idea of the degree to which research efforts result in findings that are deemed worthy of reporting in refereed journals. Furthermore, we can obtain insights into how influential (or visible) a given research effort is by seeing the extent to which the papers it produces are heavily cited in the scientific literature. The theory here is that heavily cited papers are in some sense important, while poorly cited papers are not. Literature indicators are imperfect measures of scientific productivity. However, they at least give research managers some idea of the output of research undertakings, and this can be important in assessing the worth of large and varied research programs.

Exhibit IV-3 shows one application of using literature indicators to evaluate the research efforts of Government laboratories. The data presented in this table are heavily aggregated. However, they can be examined at a

[Exhibits IV-2 and IV-3 on following pages]

Exhibit IV-2

SONY CORP. TECHNOLOGY (PATENT ACTIVITY) PROFILE FOR YEARS 1971 to 1980 USING U.S. PATENT OFFICE CLASSIFICATION SYSTEM

BAR GRAPH OF THE NUMBER OF PATENTS FOR CLASSES WITH AT LEAST FIVE PATENTS

```
                                                         NUMBER OF PATENTS
                                                  100                          200                          300
 ---------CLASSIFICATION---------   # PATS   A.I.  ..........................................................................

 029 METAL WORKING                   14.00   0.79 ###
 148 METAL TREATMENT                 15.00   2.26 ####
 156 ADHES. BOND. & MISC. CHEM        5.00   0.41 #
 179 TELEPHONY                       49.50   4.87 ##############
 204 CHEM.+ELECT. & WAVE ENERG       19.00   1.38 #####
 206 SPECIAL RECEPT. OR PACKAG        6.00   0.81 #
 242 WINDING AND REELING             42.00   4.39 ############
 307 ELECT. TRANSMIS.+INTERCON       56.00   4.99 ###############
 310 ELECT. GENER.+ MOTOR STRU        8.00   1.25 ##
 313 ELECT LMP & DISCH. DEVICE       51.00   7.97 ##############
 315 ELECT LMP & DISCH. DEVS.+       41.00   6.64 ###########
 318 ELECT+MOTIVE POWER SYSTEM       16.00   2.15 ####
 323 ELECT+POWER SUPPLY+REGULA        9.00   4.68 ##
 324 ELECT+MEASURING & TESTING       13.00   1.39 ###
 329 DEMODULATORS & DETECTORS        11.00  15.18 ##
 330 AMPLIFIERS                      74.00  20.82 ####################
 331 OSCILLATORS                     19.00   3.32 #####
 332 MODULATORS                       5.00   6.10 #
 333 WAVE TRANSM. LINES & NETW       11.00   2.42 ##
 338 ELECTRICAL RESISTORS             7.00   3.25 #
 340 COMMUNICAT.+ELECTRICAL          24.00   1.39 ######
 343 COMMUNICAT.+RADIO WAVE           5.00   0.58 #
 350 OPTICS+SYSTEMS & ELEMENTS        5.00   0.45 #
 357 ACTIVE SOLID STATE DEVICE       67.00  11.25 ##################
 358 PICTORIAL COMMUNICAT.: TV      230.00  23.42 ###############################################################
 360 DYNAMIC MAGNET. INF. STOR      172.50  25.22 ###############################################
 361 ELECT+ELECTR. SYSTS. & DE       22.00   2.50 #####
 363 ELECT POWER CONVER SYSTEM       22.00   7.68 #####
 364 ELECT COMPUT. & DP SYSTEM        5.00   0.37 #
 369 DYNAMIC INFO. STORAGE OR        53.00  22.18 ##############
 371 ERROR DETEC/COR & FAULT D        6.00   3.54 #
 428 STOCK MATERIAL OR MISC. A       12.00   0.79 ###
 430 RADIATION IMAGERY CHEM.-P        5.00   0.43 #
 455 TELECOMMUNICATIONS              64.00  14.95 #################
```

Source: Computer Horizons, Inc., Cherry Hill, N.J.

Exhibit IV-3

NUMBER OF SCIENTIFIC PAPERS PRODUCED BY FEDERAL LABORATORIES

	Clin Med.	Biomed. Research	Biology	Chemistry	Physics	Earth/ Space	Engineering Technology	Math
DOD	1,839 (-8.4)	392 (-11.0)	111 (3.5)	375 (-3.7)	936 (-5.8)	310 (-2.5)	909 (5.1)	76 (-2.4)
Federal Civilian Agencies	5,629 (4.6)	2,736 (2.1)	4,022 (-0.6)	1,141 (-1.1)	722 (-6.9)	1,414 (1.8)	1,311 (5.3)	87 (5.0)
NIH Intramural	2,041 (11.4)	1,379 (10.8)	65 (16.7)	133 (22.4)	-	-	-	-

Note: Numbers in parentheses represent the extent to which papers appeared in the top quartile (25%) of all papers produced by Government and industrial labs, where these papers were ranked according to the number of citations they received. Thus (3.2) roughly means that 3.2% more papers than the norm were heavily cited, while (-3.2) means that 3.2% fewer papers than the norm were heavily cited.

Source: Computer Horizons, Inc., Cherry Hill, New Jersey.

disaggregated level as well, so that it is possible to determine, for example, how many papers are produced by the Fermi National Laboratory in nuclear and particle physics, as well as to determine how heavily these papers are cited.

Data such as these must be interpreted very carefully. For instance, the fact that a given weapons lab does not produce papers that are highly cited does not mean that it is not adequately meeting its mission. It does suggest, however, that the published research it produces is not very influential in the scientific community.

Exhibit IV-4 shows how literature indicators can be used to evaluate Government-supported research at the program/project level. The exhibit contains actual data used in comparing two different programs in an agency. Each program is multidisciplinary, supporting a wide range of extramural projects. As the exhibit shows, the literature indicators for Program A are consistently stronger than for Program B, confirming the general consensus in the agency that Program A is scientifically stronger than Program B.

There are many additional ways in which literature indicators can be used for evaluative purposes. As output indicators, they can be compared to input indicators (e.g., funds, manpower) to come up with a measure of R&D efficiency. They can be used to model the entire Government-supported research system to determine, for example, the effects of funding cuts on immunology research in oncology.

Conclusions

Measures of R&D can serve a useful purpose in both science policy formulation and the management of R&D at the program/project level. A review of the uses of economic indicators in business and Government planning and evaluation suggests that a well-developed, comprehensive body of R&D indicators may be able to serve many varied and important functions.

The utility of R&D indicators has been realized only in recent years with the computerization of many R&D related data files. In particular, the computerization of scientific and engineering indexes/abstracts, library holdings, bibliographies, as well as the computerization of the U.S. patent files, has provided planners and evaluators with useful measures of R&D outputs. Yet many data files

[Exhibit IV-4 on following page]

Exhibit IV-4

QUANTITATIVE COMPARISON OF TWO MULTIDISCIPLINARY PROGRAMS

	Program A	Program B
Age	46.5	47.8
Years since degree	19.4	17.6
EDUCATION		
Ph.D/D.Sc	87.3%	95.6%
M.D.	9.4	2.2
Ph.D./M.D.	1.1	0.0
M.S.	2.2	2.2
PUBLICATIONS/YEAR/SCIENTIST		
Life Sciences	3.22	2.82
Physical Sciences	2.21	1.63
Social Sciences	1.00	0.57
Engineering Sciences	1.89	0.93
Agriculture Sciences	2.19	1.63

Source: J.D. Frame, "Quantitative Indicators for Evaluation of Basic Research Programs/Projects," IEEE Transactions on Engineering Management, vol. 30 (August 1983).

of potential value have not been exploited. For example, in order to get a better quantitative grasp of DOD supported R&D activities, computerized project files can be tapped to generate R&D measures (e.g., the Defense Documentation Center's Work Unit Information System can be employed). Similarly, DOE's RECON information system can serve to generate indicators of R&D effort in energy areas.

A budget of $44.3 billion is inherently difficult to manage. If budget allocations, R&D plans, evaluations of activities, etc. are made primarily on a subjective, qualitative basis, it is certain that the R&D system will be filled with inefficiencies. To the extent that valid, reliable and useful measures of R&D activity can be developed, the management process will be strengthened.

Recommendations

Investigate the state-of-the-art in R&D indicators development with a view to determining how these indicators can be employed to strengthen Federal management of R&D activities.

Support development of a comprehensive system of R&D indicators. The system should be roughly modeled after the existing system of economic indicators. Attention should focus on developing indicators at a fine level of detail. The system should be able to answer questions such as: How many molecular biologists work in the private sector? How many undergraduate students are enrolled in electrical engineering programs? What Government laboratories are most active in superconductivity research? How productive are scientists working in NHLBI labs in comparison with researchers in leading medical school cardiology departments? To what extent do French scientists have a lead over American scientists in breeder reactor technology?

Savings and Impact Analysis

The principal impact of instituting a comprehensive system of quantitative R&D measures would be to strengthen management of the multi-billion dollar Federal R&D effort. At the very least, such a system would give Government R&D managers and policymakers a fairly precise idea of the dimensions of R&D in the United States. As such, it would help Government to improve control over its R&D inventory. At best, such a system would give policymakers and managers the ability to fine tune the management of Federal R&D efforts. Unfortunately, it is very difficult to determine the level of cost savings that such a system would realize.

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APPENDIX 4

Successful corporate R&D

An industry leader reflects on the key strategic choices in managing centrally funded R&D

Roland W. Schmitt

In industry after industry, technological mastery is ever more closely linked to competitive success. But as managers try to define the proper mission for their companies' R&D units, they increasingly find that the familiar terms in which such choices get made – basic versus applied research, market-driven versus technology-driven – have outlived much of their usefulness. It is possible to stay at the cutting edge of some technologies, for example, by doing work in direct support of current businesses. With other technologies, only untargeted fundamental research will do. The author of this article draws on his many years of experience managing industrial R&D to offer a framework for thinking about the terms in which such choices ought to be made. There is no single model for doing first-rate corporate-level R&D, but there is a way of thinking that makes the different approaches – and their implications – clear.

Mr. Schmitt is senior vice president, corporate R&D, of the General Electric Company. He is also vice president of the Industrial Research Institute and chairman of the National Science Board.

Illustration by James Grashow.

The top managers of every diversified corporation must decide whether to leave the technical future of each business entirely in its own hands or to do some R&D at the corporate level. The first choice risks too much competition with the short-term demand for profits; the second, too little linkage with the needs of individual businesses. How are managers to make this decision, and – equally important – how are they to evaluate its results?

Experience in managing technology teaches us that the success of corporate-level R&D depends on:

- A sufficiently high proportion of corporate funding to permit the centralized laboratory to define its own programs.

- Close linkages with the plans, strategies, and programs of individual businesses as a basis for its own programs.

- A thorough understanding of corporate goals and strategies to guide a balance of its programs among various businesses.

- The need to hire the most outstanding people available and to link their compensation and advancement to technical performance, not to some later move into management.

There are several preeminent reasons for doing corporate R&D in the first place: synergy, interdisciplinary focus, and lead time. Some technologies may, for example, be relevant to several businesses. At General Electric, solid-state power technology – the control of electrical power for such diverse applications as industrial drives, lamp ballasts, power supplies, and appliance controls – has applications in semiconductor components, motors, appliances, and automation systems. Corporate research also has value in building interdisciplinary teams to exploit radically new technical approaches. For development into a successful product, the CT scan method of X-ray imaging required interdisciplinary skills and knowledge that were not found together in GE's traditional X-ray business. But they could be brought together at the corporate laboratory.

In addition, centralized R&D helps shorten the lead time for introducing new products and processes because this kind of lab can and should work in fields associated with, but not yet targeted on, specific business objectives. When a target becomes clear, as has happened at GE time and again in such areas as engineering plastics and solid-state power, the talent and ability are in place to move quickly. Indeed, if a company's strategy is to diversify into closely related businesses for which there is appropriate competence in-house, a corporate laboratory tied closely to existing businesses but looking beyond current horizons is essential.

With so much agreement on the reasons and criteria for corporate R&D, we might reasonably expect a further consensus on the best measures for judging both the nature and degree of its contribution in different companies. In practice, things are not so clear-cut.

A difference in approach

Compare, for a moment, the activities of Bell Laboratories with those of GE's Research and Development Center. Without question, Bell Labs has fostered much Nobel-prize quality work – on transistors, lasers, information science, solid-state electronics, and the like – and has had a profound effect on modern technology and industry. Its parent company has captured only a fraction of the vast array of industrial benefits of these advances, although it has been able to earn regulator-approved levels of return on much of its R&D costs.

GE's Research and Development Center also has a distinguished history. The list of innovations from which it has built successful businesses extends from ductile tungsten and high-volume X-ray tubes through silicones and man-made diamonds to computerized tomography for medical applications. In Nobel prizes and similar honors, Bell Labs is undeniably the leader, while GE's Research and Development Center can claim a high level of productivity in commercial output, producing five times as many patents per scientist and engineer as Bell Labs has.

How can we best understand these differences in approach?

Generic vs. targeted

Some observers view centralized R&D as trying to strike the optimum balance among basic research, applied research, and development. I do not think that these are operationally useful categories. For me, the key is whether a corporate laboratory is working at the forefront of technical areas centrally important to the parent company. Is it producing results of near-term value and laying the groundwork for future advances?

In many areas, it is entirely possible to stay at the forefront of technology by working on targeted developments alone. With robotics, for example, successful design and application require no fundamental new knowledge. Yes, the physical principles underlying such applications as welding or assembly need to be understood. Yes, it takes imaginative engineering to integrate robots with optical and tactile recognition systems, advanced controls, and CAD/CAM-based design and simulation. But these needs can all be met within programs directly addressed to robot applications and products.

So, too, in part, with expert systems and artificial intelligence. Here there is considerable scope for new knowledge about inference mechanisms, knowledge structures, and the best languages in which to express them. But, again, a lab can explore these issues in the context of specific applications. Just think about the organizations carrying out this work: medical schools; financial institutions; companies involved with natural resource location, such as Schlumberger; computer builders, such as Digital Equipment; and equipment builders, such as GE with its expert system for locomotive maintenance.

To be sure, targeted research demands challenging goals that push the limits of knowledge. For technologies like the micron and submicron integrated circuit, however, targeted programs are not enough. When the rate of progress is especially rapid (and new discoveries and inventions are common), it is not possible to ensure forefront competence by concentrating on tightly focused programs alone. In these cases, it is prudent to carry on untargeted or generic research in areas of continuing pertinence to the business. The supreme example of such an area is biotechnology, where most of the ultimate applications are still highly speculative. Today, the status of biotechnology is much like that of solid-state and semiconductor physics 30 years ago when Bell Labs, GE, and a host of other organizations mounted significant programs of generic research. Had they not, the targeted VLSI research and development of the present would not be possible.

Generic research is not, however, synonymous with a license to work on anything that happens to be interesting and fruitful. Many fascinating and very productive areas of science, such as high-energy physics, astronomy, and cosmology, are completely outside the purview of industrial R&D, generic or not. This is as it should be, since it is impossible to connect these areas of research to any viable business, now or in the foreseeable future. As a rule, U.S. industry undertakes only that research for which applications can be envisaged, even if these applications are ill-defined and remote. Lasers, for example, largely resulted from generic industrial R&D: their applications, which are now so important, took decades to fully emerge.

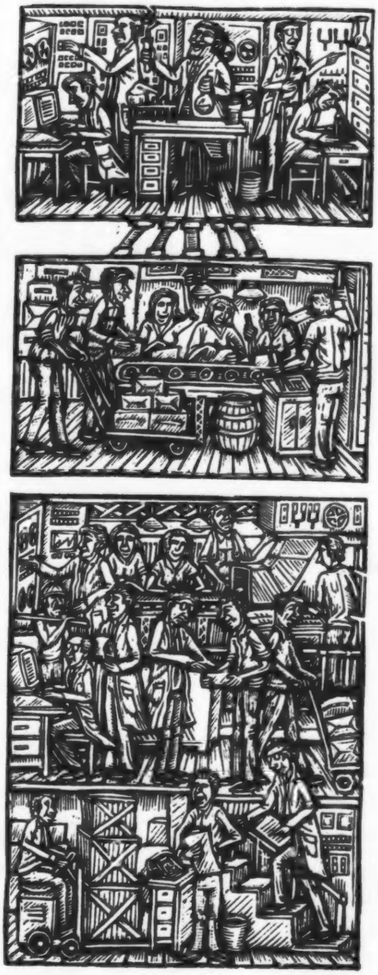
Bell Labs is justly famous for its generic research; GE's corporate lab, along with the corporate labs of many Japanese companies, for its targeted work. The Japanese also tend to pursue alternative approaches to their R&D targets, using redundancy to increase the probability of success. Although U.S. companies sometimes follow suit, the Japanese carry the practice much further along the development cycle. The U.S. company may be more efficient, but the Japanese will be more confident of achieving the goal. The history of consumer electronic products like videocassette recorders illustrates this process very well.

There is a useful distinction to make between this emphasis on redundancy and the approach of Western entrepreneurs who typically eschew both generic R&D and redundancy and concentrate instead on the final stages of targeted development. With a rich lode to mine in the generic, untargeted, and as yet underexploited research of major companies or universities, these smaller companies are almost entirely end-use focused.

Consequently, the larger companies that do generic research always run the risk of seeing it exploited by entrepreneurial organizations before it can make a real contribution to the businesses of the parent. Research in catalysis has often fallen into this category; today, a prime example is computer language research. The software for Apple's MacIntosh computer was derived in large part from basic work done at Xerox's Palo Alto Research Center.

Market-driven vs. technology-driven

A second key issue that observers often raise about corporate R&D is whether it should be guided by knowledge of market requirements or by perceived capabilities of technology. Correctly anticipating future markets is every bit as uncertain as



attaining technological goals. Even existing markets, whose size and rate of growth are well known, may respond in unexpected ways to new technology. Latent markets, which do not exist but might develop in response to a new product, pose even greater risks – and opportunities. In materials-based industries, several innovative companies – Corning, 3M, and GE's plastics, silicone, and industrial diamond businesses among them – have been quite successful in creating and exploiting such markets through a combination of generic and targeted research.

To be effective, industrial R&D must, by definition, be linked with successful marketing. The real issue, then, is not the choice between a market focus and a technology focus but the proper mode of coordination between them.

Marketing experts should be poised over the new ideas that emerge from generic research, but they should also be involved in the identification of targeted programs. These experts should not, however, give blind allegiance to the latest analytical techniques or the dogma of marketing supremacy. Rather, they should have the temperament of a research experimentalist, putting forth hypotheses about the market and devising economical and efficient market experiments. The Japanese have ably practiced this experimental approach, especially in audio and video electronic products and computer memories. They have taken chances by introducing still questionable product innovations, listening to customers' responses, and tailoring the product accordingly. In the United States, it is far more common to conduct one market research study after another, with none giving sufficiently clear answers to support an unequivocal management commitment to go to market.

In recent years formal business planning has stressed the risk-weighted, discounted rate of return on R&D projects. The professional literature bulges with methodologies for R&D project evaluation that focus on estimates of potential markets, project costs, and probabilities of success. For slow-growing and protected industries, these methods have been successful. For fast-moving and worldwide industries, they have been a disaster. The Japanese and Western entrepreneurs have outflanked and overwhelmed companies relying on such hands-off analytical models. It is inconceivable that today's successful software and computer peripheral producers – or tomorrow's biotechnology companies – started with a careful analysis of ROIs on their research projects.

What I have said about markets is somewhat less true about in-house needs for process improvement. After all, it is much easier to spot opportunities for cost reduction, improved testing, and quality control than it is to spot new markets. Process advances, however, often require highly sophisticated research and development involving a multiplicity of disciplines. The massive retooling and automation that companies such as General Motors have accomplished would have been difficult without a massive base of internal R&D.

Two kinds of success

One obvious difference between corporate R&D at Bell Labs and at GE is that Bell Labs is at least ten times larger. I do not believe, however, that size bears any direct relation to success, with the single caveat that for each technical area there does exist a minimum "critical mass" of expertise. In view of Bell's record of achievement, it is hard to have too large a laboratory; still, there are many examples of small but highly successful industrial laboratories – in specialty chemicals, in computer peripherals, in semiconductors, and elsewhere.

The main differences, then, are not related to size but to operating philosophy: for Bell Labs, an emphasis on generic programs and system efficiency in regulated markets; for GE, an emphasis on targeted programs and close coordination with highly competitive markets. Are both organizations equally successful? Obviously, the answer depends on the parameters used to measure success.

For contributions to science and technology generally, Bell stands out, although it is far from clear what the future holds for the labs in the newly deregulated universe of AT&T. One of the great ironies of modern times may be the destruction of the historic role of Bell Labs at the very moment we are most concerned about U.S. competitiveness and the revitalization of U.S. industry, to which that lab has contributed so much. For contributions to its parent company, I would say that the General Electric R&D Center comes out very well. The profits earned today by businesses directly based on corporate R&D run some four to five times the annual cost of the GE lab.

The profits of these businesses over and above the company average run almost twice the annual cost of the lab. And this measurable output is only a fraction of the total; most output is in the form of new and improved products or processes that are incorporated into existing businesses and whose effect is thus much more difficult to measure directly.

To be sure, both organizations have common elements underlying their success: the quality of people, first-rate shop and maintenance operations, and excellent systems of program management and communication, both upward and downward. Corporate R&D can fail for many reasons – not enough good people, domination by external contracts or customer pressures, lack of top management support. When it flourishes, however, the prime reason is less the choice of operating philosophy itself than the organization's knowledge of – and confidence in – that philosophy.

Every industrial laboratory must know its goal, believe in it, and organize for it. All too often, there is no agreement between corporate R&D and top corporate management on what the lab's mission and purpose are. In many companies technical managers seek to promote first-rate science while the corporate office initiates study after study to find out why no new businesses have resulted from centralized R&D. Or the labs make significant contributions to their companies while executives fret that the labs do not earn kudos for the corporation among security analysts, customers, prospective employees, and so on.

This is not, of course, an either-or situation: centralized industrial R&D organizations do not have to be replicas of either Bell Labs or GE. It is quite possible to have highly successful laboratories in which some areas of work are targeted and some generic. In fact, neither Bell Labs nor GE's R&D Center is a monolithic example of generic or targeted research. Bell Labs has made unique contributions to its parent's businesses in communication systems design and in microwave technology; General Electric sponsors generic research in areas as diverse as biophysics and coal science. It, too, has had its share of Nobel laureates.

Further, the balance of targeted and generic work depends on how centralized the company's involvement in research and development is. Some major corporations like RCA, Kodak, and Sohio concentrate R&D heavily in a single laboratory; others like IBM, Monsanto, Xerox, and GE have several. Success is possible in either mode. A single laboratory must have a mix of generic and targeted research. In a multilaboratory company, some laboratories can be more generic, some more targeted. However, researchers must know which is which and must understand what their roles are in the overall corporate strategy.

The success of a corporate R&D program becomes visible only in the light of its mission and purpose. If the choice is to adopt a generic, loosely market-coupled approach, then organization requires a strong discipline orientation and close attention to the number and excellence of contributions to the technical literature. If the choice is to adopt a targeted, tightly market-coupled approach, then organization needs a project orientation and must link its rewards to ultimate business success. Failure inevitably comes from trying to organize, appraise, and reward according to one approach while expecting results typical of the other.

R&D personnel must understand and agree with the purposes inherent in their jobs if they are to be both productive and high spirited. People working in generic programs have to recognize that they are being asked to produce new knowledge and will be appraised accordingly. People in targeted programs have to recognize that they cannot take irrelevant detours into interesting science merely out of their own curiosity. Both must accept the challenge to work in different ways at the forefront of technology. Although they take different forms, both kinds of success are essential to the long-term health of American industry.

Edison as innovation manager

As an inventor-entrepreneur, Edison presided over the process of technological change from problem identification to innovation and technology transfer. Creative fulfillment, however, came to him mostly from the inventive act, not from the other phases of technological development. He counted his patents more than his money, at least until his later years, when he began to look to industrialists like Henry Ford as status models. Edison flourished as an inventor-entrepreneur in the late 1870's and early eighties, the period when he was presiding over the invention and introduction of his system of electric lighting. His historical peers were other inventor-entrepreneurs, such men as Robert Fulton, Samuel Morse, and Cyrus Hall McCormick, who, like himself, did not rest until companies (usually those they established) were manufacturing their inventions. Edison formed a number of companies to organize his invention and the introduction of the lighting system: a company for research and development, others for manufacturing components, and another to preside over the operation of the system. In each case, he allied himself with men whose interests and capabilities complemented his own. Persons with legal and financial experience, for instance, compensated for his lack of experience and special aptitude for the complexities of organization and financing. Despite their presence, however, it was Edison, as inventor-entrepreneur, who pulled most of the strings of the complex system.

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